Research Square

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Association of air quality index with emergency department visits for acute respiratory illness in a tertiary care hospital in Mumbai

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Abstract

Background

Air pollution poses a significant public health threat, in urban cities where worsening air quality is linked to rising respiratory morbidity. This study explores the association between Air Quality Index (AQI) levels and emergency department (ED) visits for acute respiratory illness (ARI) in a tertiary care hospital in Mumbai.

Methods

A surveillance record-based study was conducted over 1036 days (March 2020–December 2022). Daily ED visits under three speciality departments were recorded. Outcome measures included the number of ARI cases, nebulization need, hospital admissions, and ventilatory support. AQI data were obtained and categorised into standard ranges from the CPCB portal. Statistical analysis was performed using negative binomial regression in STATA v15.1.

Results

During the study period, the median AQI was 83 (IQR: 58–152) and median daily ED visits for ARI were 16 (IQR: 11–20). After adjustment for the confounding effect of seasons, compared to good AQI days, satisfactory AQI was linked to a 15% higher incidence of ARI cases (IRR: 1.15; $p < 0.001$). In addition, there was a 2.13 times higher likelihood of requiring nebulization (IRR: 2.13; $p < 0.001$), a 1.26 times higher risk of hospital admission (IRR: 1.26; $p < 0.001$), and a two times higher NIV requirement (IRR: 2.00; $p < 0.001$). A significantly higher need of invasive ventilation (IRR: 1.49; $p = 0.013$) was noted for the poor and very poor AQI category.

Conclusion

Poor air quality worsens respiratory health and increases emergency care demands, highlighting focused pollution control and planned hospital preparedness in response to air pollution effect in urban areas.

INTRODUCTION

National Centre for Disease Control (NCDC) reports air pollution as a critical public health concern, contributing significantly to respiratory morbidity and mortality [(1)], with a greater impact in low-income and middle-income countries than in high income countries. India has one of the highest exposure levels to air pollution globally [(2)]. Urbanization and inadequate infrastructure further accelerate this exposure [(1)].

Mumbai, classified as a Non-Attainment City under India's National Clean Air Programme (NCAP) [(4)] faces persistent air quality challenges. Mumbai city is a district in the state of Maharashtra with a population of 30.85 Lakhs [(3)]. The city's worsening air quality is driven by factors such as dense population, rapid urbanization, vehicle emissions, industrial operations, and construction activities as reflected in the air quality index levels [(5)]. Despite action plans under NCAP targeting key pollution sources like vehicles, industries, construction dust, and waste burning, air pollution in the city remains a significant health threat, especially for respiratory illnesses [(4)] The emergency

department (ED) serves as the primary point of contact for the community when it comes to emergency healthcare services [6, 7]. These respiratory emergencies often require urgent interventions.

While substantial evidence exists supporting the acute health impacts of air pollution on hospital admissions for respiratory diseases, the majority of this information comes from research done in North America, Europe, and, to a lesser extent, Asian countries [8]. The link between air quality and respiratory health in India remains unclear, largely due to variations in study designs, methods, sample sizes, pollution levels, and exposure assessments, highlighting the need for more targeted research in the Indian context. Mumbai's deteriorating air quality provides a first-hand opportunity to investigate the health effects of air pollution in order to strengthen the body of evidence necessary for improving hospital preparedness and implementing effective environmental policies that protect public health. Having a well-prepared protocol in place for variations in air quality index over periods of time is crucial to ensure that emergency departments and hospitals are ready to address these health concerns effectively in terms of manpower and resources [9].

The Air Quality Index (AQI), simplifies complex air quality data into an easily understandable format integrating multiple pollutant concentrations into numerical value and descriptive categorisation [10]. The National Programme on Climate Change & Human Health (NPCCHH) focuses on raising public awareness and to strengthen research capacity to address the evidence gap on the impacts of climate change on human health [4]. Our research aligns with these national objectives, by providing evidence to guide public health strategies aimed at reducing respiratory diseases linked to air pollution.

The aim of this study was to assess the associations between air quality and the emergency department visit for Acute Respiratory Illness (ARI) in a tertiary care hospital in Mumbai with the goal of providing insights to improve public health interventions.

METHODOLOGY

This surveillance record-based study was conducted at a tertiary care hospital in Mumbai, India, to assess the association between air quality and respiratory illness presentations in the emergency department (ED). The study included patients who presented to the ED (emergency department) under the Medicine, Paediatrics, and Pulmonology departments from March 2020 to December 2022 i.e. 1036 observation days. Data collection was carried out by the hospital's designated team, who recorded frequency of visit's details in a structured format of daily line listing. Clinicians from the three speciality departments diagnosed, managed and reported cases as per the program's eligibility criteria for ARI. These data were compiled and submitted to the District Nodal Officer. Additionally, the analysis and monthly surveillance was submitted annually to the National Centre for Disease Control (NCDC) for review. The outcome variables recorded included the total number patients visiting of ED, the number of patients presenting with acute respiratory illnesses, and the number of patients requiring hospital admission, nebulization, non-invasive interventions, and invasive interventions (such as intubation and mechanical ventilation). To evaluate environmental factors, daily Air Quality Index (AQI) data for Mumbai were obtained from the Central Pollution Control Board (CPCB) portal, which provides publicly accessible air quality data [8].

Data for the AQI was obtained for each day of the study period and categorised according to the given six standard AQI categories as: Good (0–50); Satisfactory (51–100); Moderately polluted (101–200); Poor (210–300); Very Poor (301–400); Severe (401–500). Each of these categories was decided based on ambient concentration values of eight pollutants for which National Ambient Air Quality Standards are prescribed.

Seasonal variation was identified as a confounding factor in the study and was handled during analysis to adjust its effect. The seasonal distribution was considered as:

1. Summer: March to May;
2. Monsoon: June to September;
3. Winter: October to February

Ethical approval

for this research was not taken, as it utilized secondary data obtained from public domains and hospital records, without any direct patient interaction. All data were handled in compliance with institutional policies to ensure patient confidentiality. We summarised the frequency of respiratory illness cases requiring various levels of intervention across daily AQI levels as median and IQR. The primary outcome measure of association between AQI and the visit to emergency department due to acute respiratory illness was the analysed using negative binomial regression model adjusting for seasonal variation as one of the confounding factors with statistical software STATA version 15.1.

RESULTS

3.1 The mean AQI for the 1036 days of observation was 106.28(SD 60.33) with a median value of 83 (Interquartile range: 58–152) ranging from good to poor air quality. An outlier was recorded of AQI of 381 on 24 January 2021 indicating a severe pollution event.

3.2 The daily distribution of outcomes recorded is summarized in Fig. 1, presented as Median (Interquartile Range, IQR). Over the study period, the median number of total emergency visits per day was 43 (IQR: 35–52) while for patients visiting with complaints of Acute Respiratory Illness cases was 16 (IQR: 11–20). The need for nebulization was reported in a median of 7 patients per day (IQR: 3–11) and hospital admissions was 6 per day (IQR: 4–9). The use of Non-Invasive Ventilation (NIV) was observed in a median of 2 patients per day (IQR: 1–4). Meanwhile, the requirement for Invasive Ventilation (IV) was noted in a median of 1 patient per day (IQR: 0–2). The findings indicate a substantial burden of Acute Respiratory Illness cases requiring hospital admissions, nebulization, and ventilation support during the study period.

3.3

Table 1 indicates that as AQI worsened from good to very poor category, there was a dip in the total number of patients reporting to ED, but a rise in the number of ARI patients reporting to ED along with need for nebulization, admission, and non-invasive ventilation. Compared to days with good AQI category the average number of patients with ARI reporting to ED increased from 13 [Median=13. IQR (10-18.5)] to 16 [Median=16, IQR (14-20)] and patients requiring nebulization increased from 1 [Median=1; IQR (0-7)] to 8 [Median=8; IQR (7-11)] in the poor and very poor AQI category.

Table 1
Distribution of patients visiting emergency department with ARI complaints requiring various intervention across various levels of AQI

AQI		Patients reporting to emergency department	Patients with ARD reporting to emergency department	Patients requiring nebulisation	Patients requiring admission	Patients requiring non-invasive ventilation	Patients requiring invasive ventilation
Good (n-176)	**Median (IQR)**	48 (40.5–59)	13 (10-18.5)	1 (0–7)	6 (4–8)	1 (0–2)	1 (0.5-2)
	Mean (sd)	49.87(14.90)	14.52 (6.40)	4.02 (5.73)	6.57(4.08)	1.68 (2.03)	1.53 (1.26)
Satisfactory (n = 415)	**Median (IQR)**	42 (35–51)	16 (11–20)	7 (3–12)	5 (3–6)	2 (1–4)	1 (0–2)
	Mean (sd)	44.16(14.84)	16.36 (6.50)	7.73 (5.30)	7.64(5.24)	2.84 (2.48)	1.29 (1.48)
Moderate (n = 354)	**Median (IQR)**	41.5 (32–50)	15.5 (11–19)	6 (4–10)	6 (4–8)	2 (1–4)	1 (0–2)
	Mean (sd)	42.26(15.27)	15.67 (5.53)	7.36 (4.73)	6.49(3.35)	2.52 (1.77)	1.10 (1.25)
Poor and very poor (n = 91)	**Median (IQR)**	44 (37–55)	16 (14–20)	8 (7–11)	7 (4–10)	3 (1–4)	1 (0–2)
	Mean (sd)	46.34(13.50)	17.30 (5.03)	7 (4.03)	7.18(3.60)	2.89 (2.17)	1.53 (2.39)

3.4

Impact of Air Quality Index (AQI):

After adjustment for the confounding effect of seasons, compared to good AQI days, satisfactory AQI was linked to a 15% higher incidence of ARI cases (IRR: 1.15; 95% CI: 1.08–1.24; p < 0.001). In addition, there was a 2.13 times higher likelihood of requiring nebulization (IRR: 2.13; 95% CI: 1.82–2.49; p < 0.001), a 1.26 times higher risk of admission (IRR: 1.26; 95% CI: 1.13–1.40; p < 0.001), and a two times higher NIV requirement (IRR: 2.00; 95% CI: 1.69–2.35; p < 0.001). On moderate AQI days, total emergency visits decreased (IRR: 0.79; 95% CI: 0.73–0.85; p < 0.001), but nebulization (IRR: 2.22; 95% CI: 1.81–2.72; p < 0.001) and NIV needs (IRR: 2.15; 95% CI: 1.73–2.66; p < 0.001) increased significantly. Poor and very poor AQI days saw 15% rise in ARI cases (IRR: 1.15; 95% CI: 1.02–1.29; p = 0.018). In addition, there was a 2.5 times higher need of nebulization (IRR: 2.54; 95% CI: 1.97–3.27; p < 0.001), a 1.22 times higher admission rate (IRR: 1.22; 95% CI: 1.03–1.46; p < 0.001), and a significantly higher need of invasive ventilation (IRR: 1.49; 95% CI: 1.09–2.04; p = 0.013 (Table 2).

Impact of Seasonal Variations:

Winter saw a 17% rise in overall emergency visits (IRR: 1.17; 95% CI: 1.11–1.24; p < 0.001) and a 26% increase in ARI-related visits (IRR: 1.26; 95% CI: 1.18–1.34; P < 0.001). Nebulization (IRR: 1.44; 95% CI: 1.26–1.64; p < 0.001), admissions (IRR: 1.19; 95% CI: 1.08–1.31; p < 0.001), NIV (IRR: 1.3; 95% CI: 1.13–1.49; p < 0.001), and invasive ventilation (IRR: 1.37; 95% CI: 1.14–1.66; p = 0.001) were significantly higher as well. During monsoon, overall

emergency visits remained similar to summer (IRR: 1.05; 95% CI: 0.99–1.11; p = 0.121), but ARI visits increased by 21% (IRR: 1.21; 95% CI: 1.13–1.30; p < 0.001). Nebulization (IRR: 1.64; 95% CI: 1.41–1.91; p < 0.001), hospital admissions (IRR: 1.34; 95% CI: 1.21–1.49; p < 0.001), NIV (IRR: 1.81; 95% CI: 1.55–2.11; p < 0.001), and invasive ventilation (IRR: 2.12; 95% CI: 1.73–2.60; p < 0.001) were significantly higher, indicating seasonal variation influences ARI severity and hospital burden.

DISCUSSION

The present study demonstrates a positive association between daily AQI levels in Mumbai and emergency department (ED) visits for Acute Respiratory Illness (ARI). A shift from a good to a satisfactory AQI category was linked to a significant increase in ARI cases, as well as higher needs for nebulization, admission, and non-invasive ventilation. This association persisted on days with poor and very poor AQI, with the requirement for invasive ventilation also rising significantly compared to good AQI days. Similar findings have been reported globally. Limaye et al. observed that sudden spikes in short-term personal exposure can cause both immediate and lasting health impacts, particularly in high-risk groups such as children, the elderly, and individuals with chronic conditions [(11)]. Likewise, a study in Thailand reported a significant association between PM2.5 AQI and ED visits for pneumonia on the same day and the day following exposure [(9)]. Evidence suggests that there is a positive association between AQI, environmental PM10 or ozone concentrations and the daily number of emergency room visits due to various acute respiratory diseases as well. [(9, 16, 19, 23, 24)]

Table 2

Association of Air Quality Index (AQI) and seasonal variations with Emergency Department Visits and Healthcare interventions Among Patients with Acute Respiratory Illness (ARI). (**AQI CATEGORIES** -Good (0–50), Satisfactory (51–100), Moderately polluted (101–200), Poor (210–300), Very Poor (301–400), and Severe (401–500).)

	Patients reporting to emergency department **IRR 95% CI ; p value**	**Patients with ARI reporting to emergency department** **IRR 95% CI ; p value**	**Patients requiring nebulisation** **IRR 95% CI ; p value**	**Patients requiring admission** **IRR 95% CI ; p value**	**Patients requiring non-invasive ventilation** **IRR 95% CI ; p value**	**Patients requiring invasive ventilation** **IRR 95% CI ; p value**
AQI						
Good AQI (0–50)	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**
Satisfactory (51–100)	0.87 (0.82–0.93); P < 0.001	1.15 (1.08–1.24); P < 0.001	2.13 (1.82–2.49); P < 0.001	1.26 (1.13–1.40) P < 0.001	2.00 (1.69–2.35) P < 0.001	1.03 (0.86–1.23) P = 0.783
Moderate (101–200)	0.79 (0.73–0.85) P < 0.001	1.09 (0.99–1.20) P = 0.065	2.22 (1.81–2.72) P < 0.001	1.14 (1-1.32) P = 0.058	2.15 (1.73–2.66) P < 0.001	1.14 (0.88–1.47) P = 0.326
Poor and very poor (210–400)	0.83 (0.75- 0.92) P < 0.001	1.15 (1.02–1.29) P = 0.018	2.54 (1.97–3.27) P < 0.001	1.22 (1.03–1.46) P = 0.025	2.34 (1.81–3.04) P < 0.001	1.49 (1.09–2.04) P = 0.013
Seasons						
Summer	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**	**Ref**
Winter	1.17 (1.11–1.24) P < 0.001	1.26 (1.18–1.34) P < 0.001	1.44 (1.26–1.64) P < 0.001	1.19 (1.08–1.31) P < 0.001	1.3 (1.13–1.49) P < 0.001	1.37 (1.14–1.66) P = 0.001
Monsoon	1.05 (0.99–1.11) P = 0.121	1.21 (1.13–1.30) P < 0.001	1.64 (1.41–1.91) P < 0.001	1.34 (1.21–1.49) P < 0.001	1.81 (1.55–2.11) P < 0.001	2.12 (1.73–2.60) P < 0.001

An SRMA assessing short-term exposure to air pollution and hospital admission for pneumonia analysing 21 studies found that every 10 µg/m3 increment in PM2.5 and PM10 was associated with a 1.0% and 0.4% increase in hospital admission or ER visit, respectively [(12)]. Salvi et al in Delhi, reported that children residing in the city, exhibited a remarkably high prevalence of asthma (21.7%), and 29.4% exhibiting airflow obstruction [(13)]. They also noted significantly higher prevalence rates of cough, shortness of breath, and chest pain/tightness compared to children

residing in the less polluted cities [13]. Previous studies observed that poor air quality can trigger sudden, severe, potentially life-threatening worsening in individuals with preexisting respiratory conditions [14, 28]. Environmental research studies in cities of Delhi [18] and Mysore [19] reported similar results of association of AQI with hospital admissions. We observed a high risk of nebulisation need for patients exposed to high levels of air pollution. Parallelly a study showed that the risk of asthma quick-relief inhaler use was 5% and 6% higher by each 5 μg/m3 increase in PM10 or PM2.5, respectively [20].

Since our study was conducted during the COVID-19 lockdown, factors influencing emergency visits must be considered. The lockdown led to significant environmental improvements, with a 65–73% reduction in ambient PM10, PM2.5, and CO levels across five megacities [15]. Studies observed a 66.2% decline in non-COVID emergency visits was reported, coinciding with the rapid rise of COVID-19 cases [21]. Moreover, studies show that higher PM2.5 exposure was linked to increased COVID-19 mortality risk after adjusting for confounders [22]. Thus, our findings may reflect the combined effects of improved air quality, lockdown restrictions, and altered healthcare-seeking behaviours during this period.

Emergency visits for respiratory diseases rose 26% in winter and 21% in monsoon, with a 2.12-fold increase in invasive ventilation during monsoon, directing towards the seasonal strain on healthcare systems and the need for proactive resource planning to manage peak demands effectively. The results obtained from a study based on season-based GLM highlighted the significance of climatic factors (temperature, fog, dust storms) and air pollutants in influencing ARI incidence [25]. Higher temperatures were significantly associated with lower COVID-related admissions and mortality in July and August ($p \leq 0.05$), while relative humidity showed a positive but significant association only for admissions in June [26]. Studies from Madrid and Barcelona show that summer temperatures contributed to 16.2% and 22.3% of fatal respiratory hospitalisations, respectively [27]. However, in India's tropical–subtropical climate, seasonal impacts are more complex, with heat waves, monsoon-related infections, and winter smog driving variable peaks in respiratory burden. This requires region-specific strategies and season-sensitive public health planning to reduce preventable morbidity and mortality.

Finding shows, poor air quality significantly increases emergency visits for respiratory illnesses, especially during winter and monsoon seasons, with higher demand for nebulization, hospitalization, and ventilation support. Emergency room visits are now seen as sensitive indicator of short-term health impacts of ait pollution especially acute respiratory cases [7]. Days with poor AQI and seasonal changes along with other potential sociodemographic and environmental factors collectively amplify respiratory distress, warranting for targeted public health interventions, improved air quality management, and increased emergency care preparedness during these high-risk periods. Insights like these can guide hospitals preparedness and policy interventions to mitigate health impact caused by air pollution [18].

Our study was conducted at a prominent tertiary care hospital in a densely populated urban area in Maharashtra, which experiences a high volume of emergency visits and high number of admissions as its located in the prominent district in the state. The study reduces selection bias as; two different standard sources were considered for the exposure and outcome variables. Along with that, the team reporting the outcome data was not made aware of the research question or information about AQI of the day that served as additional masking. The research was conducted over a robust 34-month period, which also strengthens the validity of our findings. There are limitations to our study that should be acknowledged. This single-centre study limits the generalizability of findings. Reliance on secondary data from hospital records and public AQI sources may affect accuracy, while resource availability on observation days could have influenced interventions and reporting. We assessed only the short-term impact of AQI

on respiratory emergencies, without accounting for individual factors such as personal habits, indoor air quality, or time outdoors. The use of a fixed-effect model assumes uniform effects and may overrepresent highly populated areas like Mumbai. Moreover, the unique circumstances of the COVID-19 pandemic, including lockdowns and altered healthcare-seeking behaviour, may have further confounded the results.

CONCLUSION

Our study highlights the significant association between air quality and respiratory outcomes. Our findings suggest that while poor air quality is strongly associated with increased respiratory diseases and the severity of presentation highlighting the need for nebulization and non-invasive ventilation, the impact on emergency department visits may be influenced by a range of factors, including the special situations of the COVID-19 pandemic. Despite the limitations of our study, our research provides a valuable insight for understanding the implications of air pollution in Mumbai and the emergency department burden in a hospital. Such findings can help create targeted policies and strategies by hospital and healthcare system to address the influx of patients in the ER during periods of poor air quality. Future research should explore the long-term effects of air pollution on respiratory health, as well as the influence of individual factors. This study emphasizes the importance of sustained implementing policies to reduce air pollution, and addressing the need for emergency care preparedness during high-risk periods.

Declarations

Ethical approval:

Not Applicable

Consent to participate:

Not applicable. The study is based on secondary analysis of anonymized data and did not involve direct contact with human participants.

Author Contribution

Conceptualization was undertaken by Contributors 1–6 and 9, while all nine contributors were involved in study design, definition of intellectual content, data analysis, and manuscript editing; manuscript review was conducted by Contributors 1–6 and 9. Literature search was performed by Contributors 2, 6, 7, 8, and 9, and data acquisition by Contributors 1–6. Statistical analysis was carried out by Contributors 1 and 9, manuscript preparation by Contributors 1, 2, 6, 7, and 8

Data Availability

The datasets generated and analysed during this study are not publicly available due to patient confidentiality and institutional restrictions but are available from the corresponding author on reasonable request.

Consent to publish: Not applicable.

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Figures

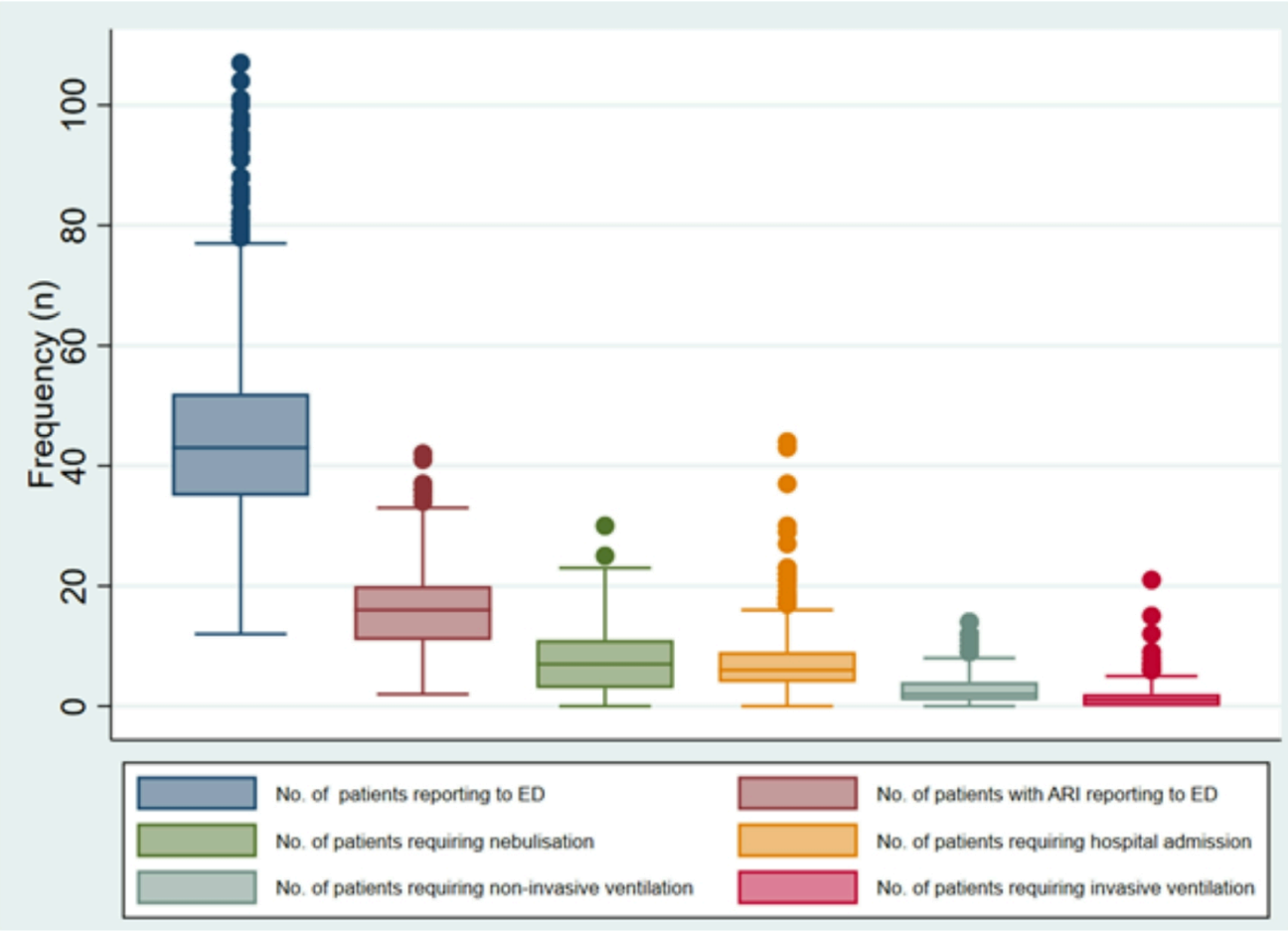


Figure 1

Visual representation of the distribution of daily emergency visits, ARI cases, and other critical care interventions using a box-and-whisker plot (observation of central tendencies and outliers)