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ORIGINAL ARTICLE

Relationship between Air Quality Index and Acute Respiratory Illness in Children

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ABSTRACT

Objective: Acute respiratory illness (ARI) is one of the top diagnoses for paediatric hospital admissions in Pakistan which is aggravated by the escalating problem of air pollution, especially over Punjab. The objective of this study was to discover the relationship of Air Quality Index (AQI) with proportion and severity of ARI in pediatric population.

Study Design: Retrospective study

Place and Duration of Study: This Study was conducted at the Punjab Rangers Teaching Hospital, Lahore over 2 years during winter smog seasons Oct 2018 - Feb 2019 and Oct 2019 - Feb 2020.

Material and Methods: Data was collected from medical records on pediatric inpatients with ARI. AQI levels were obtained from Air Quality reports and analysed with patient information using SPSS V.21.

Results: In winter smog season 2018-19, 1/5th of pediatric admissions were due to ARI, with average AQI level of 147. This fell by 50%, in the following winter, with an AQI level decline by 16%. 95% of patients with ARI were under 5 years of age and 60% were male. 65% had moderate to severe respiratory distress and 80% required oxygen supplementation. The severity of respiratory distress was observed to be worse with higher AQI levels (p=0.024), with higher frequency in bronchopneumonia (p=0.045). The proportion of cases with severe respiratory distress was 17.6% (95% CI 8.0- 31.0) over 5 months with mean AQI 138.96.

Conclusion: There is a significant association with air pollution and severity of ARI in children <5 years of age.

Key Words: *Air quality index, Acute respiratory illness, Pollution, Severity*

INTRODUCTION

Acute respiratory illnesses (ARI), infectious and non-infectious, are one of the top reasons for pediatric hospital admissions, causing 1.3 million deaths worldwide, annually.[1] ARI makes up one third of the deaths among under five years in low-income countries.[2] In Pakistan alone, around 11.74 million ARI cases are reported each year,[3] and are linked to 20-30% of all deaths among children less than 5 years.[4,5] This has also become an increasing economic burden on an already crippled healthcare system.

Ambient air pollution is the greatest global challenge we are facing, today, resulting in escalating respiratory morbidity and mortality. Children are especially susceptible and may be more exposed than adults to air pollution because children have higher ventilation rates than adults and they tend to spend more time outdoors.[6] It is capable of significantly damaging human health.[7] There is a 1.3 fold increase in risk for pneumonia in young children with long-term exposure to traffic-related air pollution and 1.8 fold increase for particulate matter less than 10 microns ($PM^{10)}$ as found in a meta-analysis of 10 European birth cohorts.[8]

In 2018, Pakistan ranked 2nd in the world's most polluted countries and Lahore was the 10th most polluted city.[9] This has resulted in the increase in hospital admissions of refractory ARI and acute exacerbations of asthma. Road traffic air pollution attributes to around 14% cases of incident asthma and 15% of all exacerbations of childhood asthma.[10] The 'winter smog' has air pollution contributed by NO_2 emissions from inner-city traffic, energy production and industrial activities and aggravated by smoke from crop-burning and low temperatures during the winter season. It extends from October to February and has increased over the last several years, especially over Punjab. In Lahore, during the 2018-2019 winter, reported levels of particulate matter ($PM^{2.5}$), measured 100-200 times higher than the World Health Organization (WHO) air quality recommended levels. The concentration of particulate matter (PM), is a common proxy indicator for air pollution of which $PM^{2.5}$ is the smaller-sized particle, (less than or equal to 2.5 mm in aerodynamic diameter [$PM^{2.5}$]).[10] Previous studies have shown positive association between exposure to air pollution (PM^{10} and NO_2) during early years of life and asthma exacerbations,[11] however it is $PM^{2.5}$ which is more hazardous, as besides depositing in large and small airways it can enter the bloodstream, as well.

With consistent association reported between air pollution and acute respiratory illnesses along with the poor air quality in Pakistan, it is puzzling why local pediatric studies on consequences of pollution on ARI have been relatively limited, to date. It is also unclear whether, exposure to air pollution influences the risk of more frequent and/or more severe respiratory infections in the pediatric population. In this study we aimed to determine the proportion of pediatric ARI hospital admissions with increasing levels of AQI and $PM^{2.5}$ over two winters, 2018-19 and 2019-20. Our objective was also to assess the impact of air pollution on the severity of respiratory illness and duration of inpatient stay, in order to recognize the association of poor air quality with increasing incidence of respiratory morbidity.

MATERIALS AND METHODS

This retrospective analysis was conducted at a tertiary care setup, Punjab Rangers Teaching Hospital, Lahore. It caters to security forces personnel and their families with a small percentage of privately treated civilian patients. All cases of pediatric inpatients (ages 1 month to 12 years) who presented with acute respiratory complaints, between the winter months of October 2018 - March 2019 and October 2019 – March 2020 were included in the study. The diagnoses were upper respiratory tract infections, bronchopneumonia, bronchiolitis and acute exacerbation of asthma. Neonates and patients with congenital heart disease and chronic respiratory illnesses were excluded from the study.

Data was retrieved from medical records of patients, admitted with acute respiratory complaints in the above-mentioned time period. All demographic, diagnostic and treatment information was entered on Microsoft EXCel application v.16, including age, sex, presenting respiratory complaint, severity of respiratory distress, duration of stay, oxygen requirement and the average Air Quality Index (AQI) of the winter months.[7,12] The data was analysed using SPSS statistics software application v.21.

Air Quality Index (AQI) and Smog*:* AQI statistics for October 2018 - March 2019 and October 2019 – March 2020 were obtained from IQ Air 2018 report[9] and local Pakistan Environmental Protection Act (PEPA) report.[7] The data was collected from ground-based air quality monitors operated by government, non-governmental organizations and individuals. Pakistani authorities were not publishing any real-time $PM^{2.5}$ air quality data until recently therefore all current data comes from non-government sensors and

the U.S. State Department. Where ground-based sensors are not available, AQI can be analysed from data modelling from satellite imagery and weather patterns to estimate air quality. Table 1 shows level of health hazards.

TABLE 1: Air Quality Index Values[1]

Air Quality Index	Level Of Health Concern	PM2.5 (ug/m^3)
<100	Good-Moderate	0-35.4
101-150	Unhealthy for sensitive individuals	35.5-55.4
>151	Unhealthy	55.5-150.4

Acute Respiratory Illness (ARI): Patients with ARI had respiratory distress with cough, tachypnea and chest indrawing developed in the last 10 days with or without fever, inclusive of infectious and non-infectious (asthma) causes. This was further classified into Upper Respiratory Tract Infections (patients presenting with cough, acute tonsillitis, pharyngitis or otitis media), bronchopneumonia (symptoms of cough, chest indrawing with or without tachypnea, requiring hospitalization for injectables or respiratory support, associated with chest X-ray changes), bronchiolitis (acute inflammatory injury of bronchioles usually caused by viral infections in children under 3 years of age) and Acute Exacerbation of Asthma or wheeze in preschool child (defined by episodic and reversible airway constriction and inflammation in response to infection, environmental allergens, and irritants.). Diagnosis has been based on the revised WHO guidelines for diagnosing and management of childhood pneumonia.[13]

Bronchiolitis, wheeze in preschool child, and Acute Exacerbation of asthma have been grouped together, since all three are characterized by inflammatory injury of airways, bronchoconstriction and wheezing, along with possible hyperinflation on chest x-ray. On the other hand, bronchopneumonia has alveolar involvement, crepitations on auscultation, with or without rhonchi and chest x-ray findings of consolidation or opacities.

Classification of respiratory distress: Respiratory Distress is a clinical state with increased respiratory rate and increased respiratory effort. Most pediatric emergencies result from respiratory distress and are commonly seen in bronchiolitis, wheeze in preschool child, asthma and pneumonia.[14] Respiratory distress was graded as mild, moderate or severe. Mild distress presented with age-specific tachypnea (>60 breaths/minute for under 1 month old, >40 breaths/min for 1mnth-1yr, >30 breaths/min for 1-5 years old and >25 breaths/min for >5 years).[15] Moderate distress has added chest wall retractions and nasal flaring ± oxygen requirement <1L. Severe respiratory distress may be defined in children with a respiratory rate >60/ minute and chest in-drawing, lethargy and inability to drink with or without oxygen requirement >1L/type 2 respiratory failure.

RESULTS

During the winter season of October, 2018 to March 2019, there were a total of 70 out of 347 patients (20.2%) admitted with acute respiratory illness. The average AQI of these months was 147. In the next winters, October 2019 to March 2020, the average AQI was 123 and acute respiratory admissions were less by almost 50% at 11.3% (51/452) admissions. Fig 1 shows number of ARI admissions and corresponding AQI levels.

In 2019, 31/51 patients were male (60%) (fig 2). More than 95% of the patients were under 5 years and of these 56.8% were under 1 year of age.

34/51(65%) had moderate to severe respiratory distress. Out of these, 27 (80%) required oxygen supplementation and 5 patients (14.7%) required additional respiratory support. 2 deaths (4% mortality) from bronchopneumonia occurred in this time period during the time AQI(PM2.5) was highest in Lahore, at average 189.

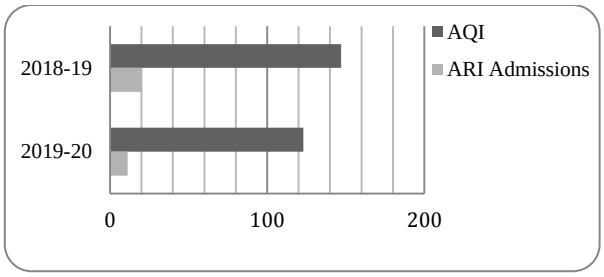

Fig 1: Relationship between AQI levels and number of ARI admissions

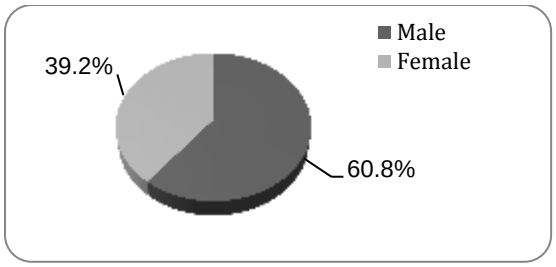

Fig 2: Gender Distribution of inpatients with ARI

Table 2 shows that the severity of respiratory distress was observed to be worse with higher AQI. There was a significant difference in frequency of severe respiratory distress with different AQI levels. (p=0.024) The higher the AQI, the more severe the respiratory distress. Duration of inpatient stay was more with higher AQI levels however this was not statistically significant. (p=0.377)

TABLE 2: Demographic information of patients 2019-20 data

ARI severity	AQI (n=44)*			p-value***
Respiratory Distress	<100	100-150	>150	
Mild	4 (57.1%)**	3 (13.6%)	3 (20%)	
Moderate	3 (42.9%)	16 (72.7%)	6 (40%)	0.024
Severe	0 (0%)	3 (13.6%)	6 (40%)	
Duration of stay				
<5 days	5 (71.4%)	11 (42.3%)	8 (44.4%)	0.377
>5 days	2 (28.6%)	15 (57.7%)	10 (55.6%)	

* Patients with no respiratory distress were excluded in this analysis.** Data is shown as count (percent).
*** P-Value was calculated using Chi-Square test

TABLE 3: Relation between No. of Acute Respiratory Illness Admissions and Mean Duration of Stay with Air Quality Index AQI ($PM^{2.5}$)

	AQI (n=12)*		p-value**
	<100	>100	
No. ARI Admissions	6±1.41	11±6.325	0.309

* Data included information of 12 months (2 winter seasons, 2018-19, 2019-20). **P-value was calculated using t-test. Levene's test of homogeneity confirmed equal variance and P-value for equal variance of assumption was used.

Intensity of respiratory distress was different in URTI, bronchopneumonia and bronchiolitis/ reactive airway disease. Table 3 shows that the highest frequency of severe respiratory distress was in bronchopneumonia patients. This difference was found to be statistically significant (p = 0.045) with 95% Confidence Interval during the period of mean AQI 138.96. Oxygen requirement was significantly higher in moderate and severe respiratory distress (p=0.00) as displayed in table 4. Proportion of cases with severe respiratory distress was 17.6% (95% CI 8.0 - 31.0) over a period of 5 months with mean AQI 138.96. Moderate respiratory distress was 49% (95% CI 35.0- 63.0)

TABLE 4: Statistical analysis of working diagnosis with severity of respiratory distress

Working Diagnosis	Respiratory Distress				Total	p-value***
	None (%)	Mild (%)	Moderate (%)	Severe (%)		
Upper Respiratory Tract Infection	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	
Acute Exacerbation of Asthma/ Bronchiolitis	1 (5.3)	7 (36.8)	9 (47.4)	2 (10.5)	19 (100)	0.045
Bronchopneumonia	5 (16.1)	3 (9.7)	16 (51.6)	7 (22.6)	31 (100.0)	
Total	**7 (13.7)**	**10 (19.6)**	**25 (49.0)**	**9 (17.6)**	**51 (100.0)**	

** Data is shown as count(percent). *** P-Value was calculated using Chi-Square test

DISCUSSION

The purpose of our study was to highlight the role of ambient air pollution in determining severity of acute respiratory illnesses in children. 95% of the patients in this study were under 5 years of age. The results of this study demonstrates that higher AQI and levels of particulate matter ($PM^{2.5}$) in air is associated with increased risk of respiratory morbidity in children, particularly, under 5 years of age. As AQI levels rose, the severity of respiratory distress increased (p=0.024) and therefore the requirement of oxygen as well (p=0.00).

Our study showed that ARI cases were more frequent when AQI was above 150, leading to higher rates of hospitalizations. There was a 16% reduction in AQI from winter 2018-19 to winter 2019-20, which brought ARI admissions down by 50% in this study, though this was not statistically significant. The sample size was small and the period of study was relatively short, therefore it cannot be excluded that a longer study duration could have led to different results. This result is consistent with a study done by Khan et al. which showed that children exposed to pollution were at 1.5 times higher risk of developing ARIs.[16] Local studies of association between air pollution and ARI are limited in pediatric population. Lanzinger et al. found a significant association of hospital admission for respiratory disease with higher ultrafine particles concentration.[17]

It was also noted that the number of cases of bronchopneumonia were higher in patients with severe respiratory distress (p=0.045). It can be indirectly stated that with higher levels of $PM^{2.5}$ in air, severe respiratory distress presented in the form of bronchopneumonia. This finding is reinforced by the Zhang, Li, Chen, et al that showed significant and stronger association between $PM^{2.5}$ levels and viral and bacterial respiratory infections in children under 3 years of age.[18] Similar findings were reported by Nhung et al. and Dherani et al. showing positive association between pollution and pneumonia-related hospitalization.[19,20] Gurley et al. showed that each hour of exposure to $PM^{2.5}$ concentrations exceeding 100 $\mu g/m^3$ was associated with a 7% increase in the incidence of acute lower respiratory infections in children aged 0–11 months.[21] This similarity in results show consistency in association found between air pollution and respiratory illness in multiple studies. The increase in severity of respiratory illnesses, especially pneumonia, may be explained by an increase in pollution-induced airway inflammation. This could be an indication that smaller size PMs induce stronger inflammatory responses, particularly the ultrafine particles (<2.5 microns) that can penetrate deeply into lung alveoli or be transported to other organs.[22]

This study had some limitations due to the small sample size and restriction of community for hospital admission due to COVID-19. A larger study including pediatric patients presenting to outpatients with acute respiratory complaints would shed more light of local impact of the increasing pollution on our children's respiratory health.

CONCLUSION

Our findings provide evidence that there is a significant association with air pollution and severity of lower respiratory tract infections in children under 5 years of age. We also found a direct proportional relationship between rising AQI and number of hospitalizations (an index of morbidity) with ARI in <5 years. This was not observed to be so in children >5 years of age in this study, as possibly, they were managed on an outpatient basis and did not require hospitalization.

Recommendations: As our cities and population size increases, so will the morbidity and mortality from air pollution. This should be considered in making long-term policy changes in improving the air quality. Government initiatives such as planting more trees, encouraging public transport, installation of car catalytic converters and safer industrialization would go a long way in improving air quality. Urban areas of countries such as Bhutan, India, and Sri Lanka with lower concentrations of PM have adopted a number of measures that have resulted in reduced urban air pollution, Pakistan has yet to follow suit and is paying the costs of increasingly high outdoor air pollution. The problem of smog over Lahore and other major cities of Punjab province was recognized in 2014[23] and Punjab Clean Air Action Plan was drawn up thereafter.[24] The plan was

revised in June 2021, after lack of implementation and continuing rise in PM and AQI levels.

Conflict of interest: Nil

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