INTERNATIONAL JOURNAL OF CARDIOVASCULAR RESEARCH & INNOVATION
Apr-Jun 2024, VOL. 2, ISSUE 2, pp. 1-8
https://doi.org/10.61577/ijcri.2024.100007

RESEAPRO JOURNALS

ORIGINAL ARTICLE

OPEN ACCESS

# Impact of air pollution on coronary artery disease: A qualitative study

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## ABSTRACT

**Background:** Coronary Artery Disease (CAD) is a growing public health concern, especially in polluted urban areas like Delhi. Air pollution exacerbates CAD progression through systemic inflammation and oxidative stress, further aggravated by the environmental and psychological stress prevalent in such areas.

**Introduction:** This study focuses on understanding the impact of air pollution on CAD management from the perspective of healthcare professionals in Delhi. While quantitative data exists linking pollution to cardiovascular diseases, qualitative insights from cardiologists and interventional cardiologists remain underexplored. This study addresses the gap by collecting their experiences in managing CAD in high-pollution areas.

**Methods:** A qualitative research design was employed, using semi-structured interviews and questionnaires to gather data from healthcare professionals. Thematic analysis was conducted to identify patterns in the responses, focusing on the perceived impact of air pollution on CAD progression, treatment challenges, and recovery.

**Results:** The findings reveal that air pollution accelerates CAD progression, with higher acute coronary events during periods of high pollution. Lifestyle changes alone are insufficient for advanced CAD, necessitating medical interventions. Patients exposed to pollution face slower recovery after procedures like angioplasty, with a significant lack of patient awareness regarding pollution's impact on cardiovascular health.

**Conclusions:** Air pollution poses significant challenges to CAD management. Urgent action from policymakers and healthcare providers is needed to mitigate its effects through stricter emission controls, public health education, and integrated patient care. Without such interventions, the burden of CAD in polluted environments will continue to rise.

## KEYWORDS

Cardiovascular diseases; Coronary artery disease; Air pollution; Angioplasty; Patient care

## ARTICLE HISTORY

Received 02 May 2024;
Revised 31 May 2024;
Accepted 07 June 2024

## Introduction

Coronary Artery Disease (CAD) is a major global public health concern, with urban environments posing unique challenges due to environmental and lifestyle factors. In densely populated cities like Delhi, air pollution plays a significant role in the progression of cardiovascular diseases, including CAD [1]. Pollutants such as particulate matter (PM2.5 and PM10) and nitrogen oxides (NOx), originating from vehicular emissions, industrial activities, and construction, are prevalent in Delhi. These pollutants enter the respiratory system and bloodstream, leading to systemic inflammation, oxidative stress, and endothelial dysfunction, all of which contribute to the development and worsening of CAD [2].

While the physical effects of air pollution are well-established, the psychological stress caused by living in polluted and congested urban areas also worsens cardiovascular risk. Chronic stress, common in urban settings, leads to elevated blood pressure, increased inflammation, and other physiological responses that exacerbate CAD. The combined impact of environmental pollution and psychological stress presents significant challenges for healthcare providers managing CAD in cities like Delhi [3].

Despite extensive quantitative research linking air pollution to CAD, the perspectives and experiences of healthcare professionals working in polluted environments remain underexplored. Existing studies predominantly focus on pollution levels, clinical outcomes, and hospital admissions, offering robust quantitative data. However, there is a lack of qualitative research examining how healthcare providers such as cardiologists and interventional cardiologists perceive and manage the impact of air pollution on CAD [4]. This gap in the literature is critical because healthcare professionals engaged in diagnosing and treating CAD patients in highly polluted areas can provide valuable insights into the challenges posed by environmental factors.

This study seeks to address this gap by collecting qualitative data from healthcare providers in Delhi, including cardiologists and interventional cardiologists. The aim is to understand how these professionals perceive air pollution's contribution to CAD, the challenges they encounter in treating patients, and the strategies they employ to mitigate the combined effects of pollution and stress [5]. The lack of region-specific qualitative data limits the current

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understanding of how environmental and psychological stressors interact in CAD management. By addressing these gaps, this research aims to provide a more nuanced understanding of the challenges healthcare providers face in managing CAD in one of the world's most polluted cities [6].

This research has significant implications for both clinical practice and public health policy. For healthcare providers, understanding the impact of environmental factors like air pollution on CAD patients is essential for developing comprehensive treatment plans [7]. Integrating knowledge of pollution's effects into patient care could lead to targeted interventions, including early diagnostic screenings, personalized treatment protocols, and patient education on minimizing exposure to pollutants. This approach could improve outcomes, particularly for high-risk individuals with pre-existing cardiovascular conditions [8].

From a policy perspective, this research underscores the urgent need for stronger air quality regulations and urban planning initiatives aimed at reducing environmental health risks. Stricter emissions standards, cleaner energy alternatives, and the expansion of green spaces are critical to lowering pollution levels in cities like Delhi. Public health campaigns highlighting the link between air pollution and cardiovascular disease can also encourage preventive behaviours, such as reducing outdoor activities during peak pollution periods or using protective measures like air purifiers [9].

The following research questions guide this study:

1. How do cardiologists and interventional cardiologists in Delhi perceive the impact of air pollution on the progression and management of CAD?
2. What specific challenges do healthcare professionals face when diagnosing and treating CAD in high-pollution urban environments?
3. What strategies do healthcare providers recommend for mitigating the combined effects of air pollution and stress in CAD patients?

The objective of this study is to explore the qualitative experiences of healthcare professionals in Delhi, focusing on how air pollution influences CAD management. Through interviews with cardiologists and interventional cardiologists, the study will gather insights into the challenges these professionals face and the strategies they recommend for mitigating the effects of both pollution and stress on cardiovascular health. The findings will contribute to the existing body of knowledge on how environmental factors affect chronic diseases and provide valuable guidance for clinical practices and public health policies aimed at improving cardiovascular health in polluted urban centers (Figure 1) [10].

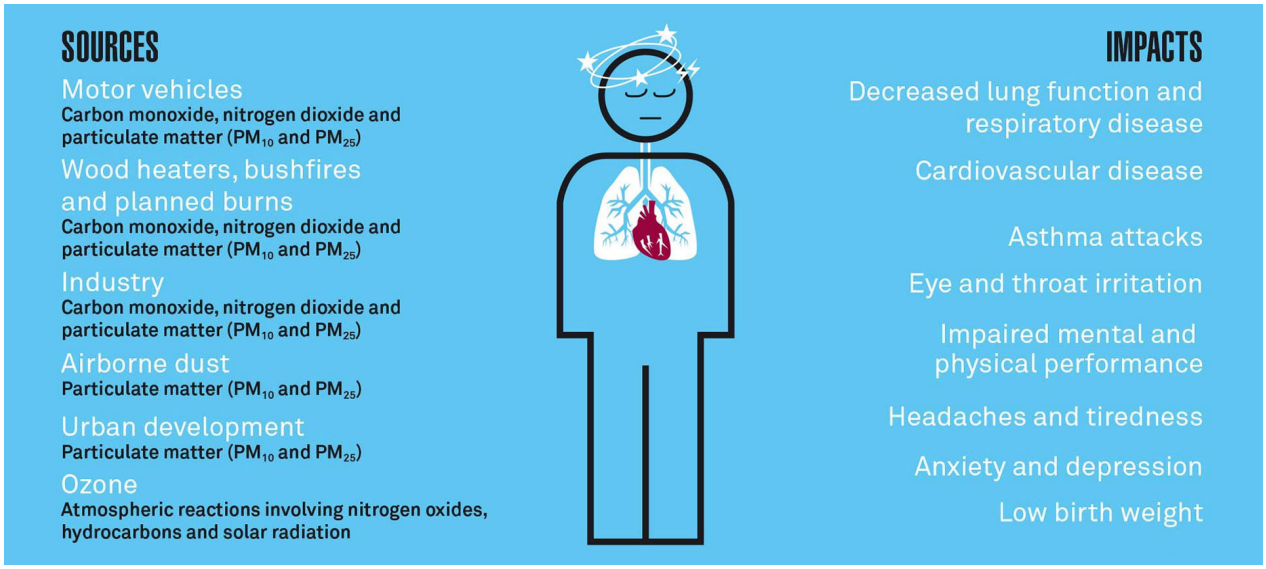


**Figure 1.** Infographic outline showing effects of air pollutants on heart (Image from office of the Commissioner for Sustainability and the Environment Australia).

## Methodology

This study employed a qualitative research design to explore the perspectives of healthcare professionals, specifically cardiologists and interventional cardiologists, on the impact of air pollution on CAD management in Delhi. Semi-structured interviews and questionnaires were utilized as the primary methods of data collection. Semi-structured interviews provided flexibility, allowing the interviewer to explore key topics while enabling the healthcare professionals to elaborate on their experiences. This approach ensured that the data collected captured both predefined areas of inquiry and emergent themes from the professionals' detailed reflections on their practice [11].

The use of questionnaires helped to standardize specific responses, ensuring that certain aspects of CAD management under pollution conditions were uniformly addressed. The mixed-method approach of interviews and questionnaires allowed for a comprehensive understanding of the challenges faced by these professionals in managing CAD patients, particularly in the context of a high-pollution urban environment like Delhi. Interviews were conducted either in person or via online platforms, depending on the availability of the healthcare professionals, ensuring flexibility and access across diverse clinical settings (Table 1) [12].



https://doi.org/10.61577/ijcri.2024.100007

**Table 1.** Summary of the process of data collection and analysis through qualitative interview process.

| Process Step | Explanation |
|---|---|
| Planning Phase | 1. Identify research questions and objectives.<br>2. Determine the scope and methodology of the study. |
| Interview Design | 1. Develop interview questions aligned with research objectives.<br>2. Choose interview format (structured, semi-structured, or unstructured). |
| Participant Recruitment | 1. Select participants based on the study's criteria.<br>2. Obtain informed consent and brief participants. |
| Conducting Interviews | 1. Conduct interviews, recording responses.<br>2. Ensure consistent interaction with participants. |
| Data Transcription | 1. Convert audio/video recordings into written format.<br>2. Maintain accuracy and completeness in transcription. |
| Coding and Categorization | 1. Assign codes to relevant segments of data.<br>2. Group similar codes into categories or themes. |
| Theme Identification | 1. Identify patterns and overarching themes from categorized data.<br>2. Ensure themes reflect the core findings of the interviews. |
| Data Interpretation | 1. Analyze themes in the context of research questions.<br>2. Explore relationships and significance of findings. |
| Reporting and Presentation of Findings | 1. Compile findings into a structured report.<br>2. Present conclusions and implications of the study. |

## Data collection methods

The data collection process involved two key approaches: semi-structured interviews and questionnaires. The semi-structured interviews provided detailed qualitative data, focusing on the healthcare professionals' experiences in managing CAD in a high-pollution context. The interviews were designed to explore key areas such as the role of air pollution in the progression of CAD, clinical challenges in diagnosis and treatment, and the impact of environmental stressors on patient outcomes [13]. The open-ended nature of these interviews allowed the healthcare professionals to provide nuanced insights into the interaction between air quality and cardiovascular disease management.

The questionnaires were designed to gather structured data, particularly regarding clinical protocols and management strategies. The questions addressed key aspects of CAD management, such as the use of diagnostic tools like angiography and echocardiography, as well as the pharmacological treatments commonly prescribed. The combination of interviews and questionnaires allowed for the collection of both qualitative insights and quantitative data, providing a comprehensive understanding of the clinical challenges posed by air pollution in CAD management [14].

## Data analysis

Data analysis was conducted using thematic analysis, a method that allows for the identification and interpretation of patterns within qualitative data. The interviews were transcribed verbatim, and the transcriptions were reviewed thoroughly to ensure that the content was fully understood. The analysis began with open coding, where segments of the text were labeled with specific codes representing key concepts, such as impact of air pollution on CAD and clinical challenges in polluted environments [15].

Once the initial coding was completed, the codes were grouped into broader categories to identify common themes across the data. These categories were refined through review and discussion within the research team, ensuring consistency in how the data were interpreted. Questionnaire data were also analyzed, with responses coded and compared to the qualitative data from the interviews. This process allowed for the integration of quantitative findings with qualitative insights, ensuring that the analysis captured both the depth and breadth of the healthcare professionals' experiences (Figure 2) [16].

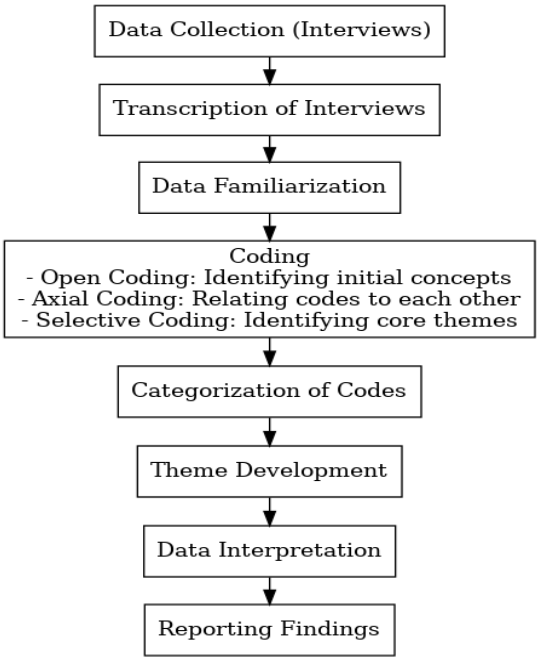


**Figure 2.** Flowchart showing the detailed process of data collection and analysis.



https://doi.org/10.61577/ijcri.2024.100007

## Ethical considerations

Ethical approval for the study was granted by the institutional ethics review board of the lead hospital. All healthcare professionals were provided with detailed information about the study's aims and procedures before participation. Written informed consent was obtained from all participants, ensuring that they fully understood their rights, including the option to withdraw from the study at any time without penalty [17]. To ensure confidentiality, all identifying information was anonymized. Participants were assured that the findings would be reported in aggregate form, with no individual healthcare professional being identifiable in the final publication. These ethical protocols ensured that the study was conducted in accordance with the highest standards of data protection and participant confidentiality, fostering an environment in which healthcare professionals could openly share their clinical insights and experiences [18].

## Results

We describe herein the key findings and themes based on the qualitative interviews on the impact of air pollution on CAD management. This involved collecting qualitative data through interviews and questionnaires before conducting content analysis to identify and interpret themes. Table 2 summarizes the questions asked, the themes identified, the responses from participants, and the key findings and themes derived from the content analysis.

**Table 2.** Summary of Qualitative Interview Responses and Key Findings on the impact of air pollution on CAD management.

| Questions | Theme | Participant Answers | Answer Content Analysis |
|---|---|---|---|
| How does air pollution impact the progression of CAD? | Impact of Pollution on CAD Progression | Participant 1: Pollution accelerates CAD progression by increasing inflammation, leading to faster plaque buildup in arteries. Participant 2: We often see a spike in acute coronary events, especially during times of high pollution, which worsens pre-existing heart conditions. | Both agree that pollution aggravates CAD, with Participant 2 highlighting pollution's role in triggering acute coronary events. |
| How effective are lifestyle changes in controlling CAD? | Role of Lifestyle Changes | Participant 1: Lifestyle changes like diet and exercise improve CAD symptoms significantly, though adherence can be a challenge. Participant 2: Lifestyle changes are crucial, but for severe cases, surgery or medication remains necessary alongside these adjustments. | While lifestyle changes are important, both participants emphasize that for advanced CAD, additional interventions are often required. |
| How important is medication in long-term CAD management? | Long-Term Medication in CAD | Participant 1: Medications like statins and beta-blockers are crucial to managing long-term CAD, reducing the risk of heart attacks. Participant 2: Post-surgery, medications are indispensable to prevent restenosis and manage underlying conditions. | Both stress the importance of medication, noting that it is vital both in long-term CAD management and in preventing complications post-intervention. |
| Are patients aware of air pollution's effect on heart health? | Patient Awareness of Pollution | Participant 1: Most patients do not realize the effect of pollution on their heart health until we explain it during consultations. Participant 2: There's a significant lack of awareness, and many patients are surprised when we link their symptoms to air pollution. | Both recognize a gap in patient awareness, which suggests a need for more patient education on the cardiovascular impacts of air pollution. |
| Do you notice seasonal fluctuations in CAD cases? | Seasonal Influence on CAD | Participant 1: Yes, we see more cases in winter due to colder weather and higher pollution levels, leading to worsened symptoms. Participant 2: During winter, the number of CAD cases increases, with many patients experiencing acute episodes due to the poor air quality. | Both observe a rise in CAD cases during the winter, indicating that colder temperatures and pollution are important triggers for heart complications. |



https://doi.org/10.61577/ijcri.2024.100007

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|---|---|---|---|
| What are the long-term outcomes for CAD patients in polluted areas? | Long-Term Prognosis in Polluted Areas | Participant 1: Patients from polluted areas tend to have worse outcomes, with faster disease progression and frequent hospitalizations.<br>Participant 2: Long-term outcomes are poorer, even after intervention, as pollution complicates recovery and increases recurrence rates. | Pollution negatively impacts both disease progression and post-surgical recovery, stressing the need for continuous monitoring and preventive measures. |
| Can public health initiatives help reduce CAD rates? | Public Health Initiatives | Participant 1: Yes, if public health initiatives focus on reducing air pollution and raising awareness, we could lower CAD rates.<br>Participant 2: Clean air policies are crucial, but they must be paired with education to ensure patients understand the risks and take precautions. | Public health measures, particularly those focused on air quality, could have a significant impact on CAD incidence, especially with increased awareness. |
| How do you incorporate air quality discussions into patient consultations? | Discussing Air Quality as a Risk Factor | Participant 1: I talk about air quality with every high-risk patient, especially those who live in heavily polluted areas.<br>Participant 2: It's part of my regular consultations, especially for follow-ups, where we focus on environmental triggers like pollution. | Both integrate air quality discussions into their patient consultations, stressing the importance of environmental risk factors in ongoing CAD management. |
| Have you seen an increase in angioplasty procedures due to pollution? | Frequency of Angioplasty in Polluted Areas | Participant 1: Many patients from polluted areas are referred for angioplasty, often presenting with severe blockages requiring immediate intervention.<br>Participant 2: Yes, I've noticed more frequent angioplasties, especially in younger patients who develop CAD earlier due to pollution. | Both participants highlight the link between pollution and the need for more frequent surgical interventions like angioplasty, especially in high-risk patients. |
| Are there challenges in recovery after angioplasty in polluted areas? | Post-Angioplasty Recovery Challenges | Participant 1: We see prolonged recovery times and more frequent complications, especially when pollution levels are high during recovery.<br>Participant 2: Recovery is often slower in patients from polluted areas, with more complications post-surgery, including recurrent symptoms. | Both observe that pollution hinders recovery after angioplasty, with patients experiencing slower healing and more post-surgical complications. |
| Do you recommend any specific measures before surgery for CAD patients? | Pre-Surgery Preventative Measures | Participant 1: Pre-surgery, I advise patients to avoid heavy pollution exposure and focus on stabilizing their symptoms with medications.<br>Participant 2: Yes, I recommend minimizing exposure to outdoor pollution and optimizing medication before surgery to improve outcomes. | Both emphasize the importance of reducing pollution exposure and optimizing medical management before surgery to enhance surgical outcomes. |
| Do stents help manage CAD in polluted areas? | Role of Stents in Pollution Management | Participant 1: Stents do help, but patients need ongoing monitoring, especially in polluted areas, to avoid recurrence of symptoms.<br>Participant 2: Stents are effective in managing blockages, but pollution can lead to restenosis, so we have to monitor closely. | Stents are useful but require close follow-up, as pollution can increase the likelihood of restenosis and necessitate further interventions. |



https://doi.org/10.61577/ijcri.2024.100007

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|---|---|---|---|
| Do patients from high-pollution areas have more coronary events? | Pollution and Coronary Events | Participant 1: Pollution clearly acts as a trigger for acute coronary events, especially in patients with underlying heart issues.<br>Participant 2: Yes, we see more heart attacks and other acute events in patients from highly polluted areas, often requiring immediate care. | Both note that pollution significantly increases the incidence of acute coronary events, indicating that patients in high-pollution areas are at higher risk. |
| What does long-term follow-up look like post-surgery in polluted areas? | Long-Term Post-Surgery Follow-Up | Participant 1: I monitor these patients closely, focusing on both their medical recovery and advising them to reduce pollution exposure.<br>Participant 2: Post-surgery, patients need frequent check-ups to ensure stent patency and to monitor for recurring symptoms due to pollution. | Long-term follow-up is essential in polluted areas, with a focus on monitoring stents and reducing environmental exposure to improve patient outcomes. |
| What advice do you give patients post-surgery to minimize pollution impact? | Minimizing Pollution Impact Post-Surgery | Participant 1: I also recommend monitoring air quality and making lifestyle adjustments, like avoiding physical exertion when pollution is high.<br>Participant 2: I advise them to avoid outdoor activities during high-pollution days and use air purifiers at home to reduce exposure. | Both emphasize environmental controls, like avoiding outdoor exposure during high-pollution periods and using air purifiers, to help patient's post-surgery. |

## Discussion

The findings from this study emphasize the severe impact of air pollution on the progression and management of Coronary Artery Disease (CAD) in highly polluted environments like Delhi. Both participants observed that air pollution accelerates CAD progression by causing systemic inflammation, oxidative stress, and endothelial dysfunction. These physiological effects lead to faster plaque buildup in the arteries, which increases the frequency of acute coronary events, especially during high-pollution periods such as winter. These observations align with existing research, such as Liao et al. (2021), who demonstrated that exposure to PM2.5 significantly increases the risk of myocardial infarction by exacerbating atherosclerosis [19]. Similarly, Huang et al. (2021) reported that short-term exposure to elevated pollution levels can significantly heighten the incidence of heart attacks and other acute cardiovascular events, a finding that supports the experiences shared by the participants [20].

The participants also noted that while lifestyle changes, including dietary modifications and exercise, are beneficial for managing early-stage CAD, they are often insufficient for advanced cases, which require medical interventions such as angioplasty. This observation is consistent with clinical guidelines for CAD, which advocates a combination of lifestyle modification and pharmacological treatment, particularly for high-risk individuals. Studies by Figtree et al. (2023) highlighted the importance of medications such as statins, beta-blockers, and ACE inhibitors in reducing the risk of recurrent coronary events by controlling blood pressure, lowering cholesterol levels, and reducing inflammation [21]. The participants further emphasized the importance of optimizing medical management before surgical interventions, which is supported by Hussain et al. (2023), who emphasized the need for perioperative care tailored to CAD patients in polluted environments [22]. Proper medical management, they noted, not only improves surgical outcomes but also reduces the risk of post-operative complications, which tend to be higher in patients exposed to long-term pollution.

Another critical finding was that pollution significantly hinders recovery after surgical interventions like angioplasty. The participants observed that patients exposed to high levels of air pollution experienced slower healing and more frequent post-operative complications. These findings are consistent with the research of Motairek et al. (2023), who found that patients living in polluted environments exhibited longer recovery times following coronary interventions, largely due to the prolonged systemic inflammation caused by chronic exposure to pollutants [23]. This prolonged inflammatory response impairs the body's natural healing processes, increasing the risk of restenosis and necessitating closer post-operative monitoring. Zare et al (2016) also emphasized the importance of continuous follow-up and treatment adjustments for patients recovering from angioplasty in highly polluted areas, a point echoed by the participants in this study [24].

A significant concern highlighted by both participants was the lack of awareness among individuals regarding the link between air pollution and cardiovascular health. This lack of understanding delays diagnosis and intervention, leading to worse outcomes for CAD patients. Public health education campaigns aimed at raising awareness of the cardiovascular risks posed by air pollution are crucial. This observation is supported by Connor et al. (2020), who found that increased patient education on environmental risk factors improved cardiovascular disease management [25]. Their study



https://doi.org/10.61577/ijcri.2024.100007

concluded that patients who understood the link between air pollution and heart disease were more likely to adhere to prescribed treatments and adopt protective behaviors, such as reducing outdoor activities during high-pollution periods and using air purifiers at home.

The participants also observed a notable increase in CAD cases during the winter months, which they attributed to the combined effects of colder temperatures and elevated pollution levels [26]. Testa et al. (2022) confirmed that both cold weather and increased pollution act as triggers for acute coronary events. Cold temperatures induce vasoconstriction, which raises blood pressure and exacerbates the inflammatory effects of pollution, increasing the risk of heart attacks [27]. This seasonal variation underscores the importance of continuous monitoring and preventive strategies during periods of high pollution, particularly in urban areas that experience significant seasonal pollution spikes [28].

While stents are effective in managing CAD, the participants emphasized that their long-term success is often compromised in patients exposed to high levels of pollution. This observation aligns with findings by Misumida et al. (2016), who demonstrated that pollution increases the likelihood of restenosis, necessitating more frequent follow-up visits and adjustments to medical management [29]. Long-term follow-up is especially critical in polluted environments, as patients are at greater risk of post-surgical complications, even after successful interventions. The participants recommended reducing exposure to pollution and closely monitoring stents to prevent restenosis and improve patient outcomes [30].

The emphasis placed by the participants on integrating discussions of air quality into patient consultations and promoting environmental controls, such as avoiding outdoor activities during peak pollution hours, is aligned with numerous public health recommendations. Rajagopalan et al. (2024) demonstrated that policies aimed at reducing vehicular emissions and increasing urban green spaces significantly reduced the incidence of cardiovascular disease in polluted cities. These public health interventions, combined with individual protective measures, can help alleviate the burden of CAD in heavily polluted environments like Delhi [31].

## Conclusions

This study demonstrated a clear link between air pollution and the progression of Coronary Artery Disease (CAD) in Delhi, with long-term exposure to pollutants accelerating CAD through systemic inflammation and oxidative stress. Participants reported an increase in acute coronary events during periods of high pollution, particularly in winter. Additionally, recovery from procedures like angioplasty was slower in polluted environments, primarily due to chronic inflammation and prolonged exposure to environmental stressors. A key finding was the significant lack of awareness among individuals regarding the cardiovascular risks posed by air pollution and stress.

Given the clear evidence of the detrimental effects of air pollution on CAD, immediate action is required from policymakers, healthcare providers, and public health experts. Policymakers should enforce stricter emission controls and promote green infrastructure to improve air quality. Healthcare providers must incorporate environmental risk assessments into regular consultations, providing tailored advice for at-risk individuals, such as using air quality monitors and avoiding outdoor activities during high pollution periods. Public health campaigns should prioritize educating the population on the cardiovascular risks of both pollution and stress, encouraging protective behaviors and early intervention strategies.

Tackling the rising burden of CAD in polluted urban environments requires urgent collaboration between healthcare systems and environmental policymakers. Ensuring cleaner air and integrating environmental health into routine patient care are essential steps toward reducing the health risks for at-risk populations. Without decisive action, the harmful effects of air pollution and environmental stress will continue to exacerbate cardiovascular disease, placing millions at increased risk.

## Disclosure Statement

No potential conflict of interest was reported by the authors.

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