

Original Research

# Understanding COPD Patients' Perspectives on Utilizing Strategies to Limit Their Exposure to Wildfire Smoke

Jimmy Yao, MD, MPH<sup>1</sup> Caitlin M. Lydon, MPH<sup>1</sup> Nina Pak, PhD<sup>1</sup> Kathleen A. Daly, BS<sup>1</sup> Mary Meyer, MD, MPH<sup>2</sup>  
Nadia Hansel, MD, MPH<sup>3</sup> Mark T. Dransfield, MD<sup>4</sup> Stacey Alexeeff, PhD<sup>1</sup> Andrea Altshuler, PhD<sup>1</sup>  
Laura C. Myers, MD, MPH<sup>1</sup>

## Abstract

**Background:** A translation gap exists in how patients with chronic obstructive pulmonary disease (COPD) utilize mitigation strategies to limit exposure to wildfire smoke. This study examines patients' points of view about barriers and facilitators of strategy uptake.

**Methods:** We performed semistructured, virtual interviews with members of Kaiser Permanente Northern California until thematic saturation. We recruited participants aged  $\geq 65$  in the lowest quartile of socioeconomic status because they are disproportionately exposed to air pollution with fewer resources to mitigate exposure. Qualitative analysis was performed using inductive and deductive approaches.

**Results:** Of 90,696 adults, we interviewed 31 in January 2025. Participants were racially and ethnically diverse (19% Black, 10% Hispanic, 3% Native American, 68% non-Hispanic White), from 10 counties. Three major themes were: (1) patients tended to get wildfire and air quality information from internet and smartphone apps, not clinical encounters, but expressed openness to receiving information from clinicians, (2) there appeared to be modifiable barriers to uptake of mitigation strategies, such as education and supplying equipment (e.g., masks, air cleaners), and (3) patients preferred real-time alerts sent to their phones from trusted sources, such as health care entities, to change their behavior during periods of poor air quality.

**Conclusions:** By understanding patients' perspectives about their relationship with wildfire smoke, we gained practical information to begin designing interventions to protect patients' health during periods of poor air quality.

1. Division of Research, Kaiser Permanente Northern California, Pleasanton, California, United States
2. The Permanente Medical Group, Diablo Service Area, Walnut Creek, California, United States
3. Department of Medicine, Johns Hopkins Medicine, Baltimore, Maryland, United States
4. Division of Pulmonary/Critical Care, University of Alabama at Birmingham, Birmingham, Alabama, United States

## Abbreviations:

**COPD**=chronic obstructive pulmonary disease; **NDI**=neighborhood deprivation index; **SD**=standard deviation

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## Address correspondence to:

Laura C. Myers, MD, MPH  
Kaiser Permanente Northern California  
Division of Research  
Pleasanton, CA 94588  
Phone: (925) 433-3491  
Email: [Laura.c.myers@kp.org](mailto:Laura.c.myers@kp.org)

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***This article has an online supplement.***

## Introduction

Long-term exposure to wildfire smoke is associated with increased mortality.<sup>1</sup> As a direct result of climate change, wildfire smoke is responsible for a growing fraction of particulate matter air pollution in the United States.<sup>2</sup> Patients with chronic obstructive pulmonary disease (COPD) are at especially high risk of exacerbation due to wildfire smoke, as up to 30% of exacerbations are due to environmental triggers.<sup>3,4</sup> Existing literature supports a dose response relationship with one study reporting a 2.7% increase in COPD exacerbations for every 10 $\mu\text{g}/\text{m}^3$  rise in particulate matter exposure.<sup>5,6</sup> Although people living on the West Coast are considered to be at highest risk of exposure to wildfire smoke, smoke originating on the West Coast travels east with the jet stream, putting the entire country at risk.<sup>7,8</sup>

The health burden of wildfire smoke falls disproportionately on vulnerable populations, especially those with low socioeconomic status.<sup>9-11</sup> This is thought to be due to lower quality housing structures, which allow particles to enter the indoor space through cracks around windows and door frames, and poorly filtered air coming through the heating and ventilation system.<sup>12-14</sup> Additionally, vulnerable populations have fewer educational and financial resources to buy protective equipment, including air cleaners, to safeguard themselves during periods of poor air quality.<sup>9</sup>

In a workshop report, an American Thoracic Society panel identified the following strategies for mitigating wildfire smoke exposure at the individual level: (1) staying indoors, (2) wearing N95-rated respirator masks when outdoors, (3) using vehicle air recirculation settings, (4) periodically replacing the home's ventilation system filters, (5) sealing windows/doors, and (6) utilizing portable high-efficiency particulate air cleaners.<sup>15</sup> These mitigation strategies are recommended by the Environmental Protection Agency and Centers for Disease Control and Prevention.<sup>16,17</sup> Despite the ability of indoor air cleaners to reduce indoor particle concentrations by 40%–80% and reduce respiratory symptoms in COPD patients when used over 6 months in an urban setting,<sup>18</sup> studies have shown limited uptake of portable air cleaners (and other mitigation strategies).<sup>12</sup>

In this study, we performed qualitative interviews with patients aged  $\geq 65$  years old with COPD and low socioeconomic status, who lived in close geographic proximity to historically large wildfires. The goal was to gain insights from patients to inform the design of intervention(s) that can be deployed to increase uptake of the aforementioned mitigation strategies and protect this vulnerable patient population from the harm of wildfire smoke.

## Methods

This study was approved by the Kaiser Permanente Northern California Institutional Review Board (Protocol 2131623-10) with a requirement for verbal consent.

### ***Design and Setting***

We conducted qualitative, semistructured interviews, in which we enrolled patients with COPD within Kaiser Permanente Northern California, the largest integrated health system in the United States, serving >4.5 million patients as a health insurer and health care provider. Supplement S1 in the online supplement contains the 32-item checklist for the Consolidated Criteria for Reporting Qualitative Studies.

### ***Developing the Interview Guide***

We developed an interview guide at a  $\leq 5$ th grade literacy level with 3 sections: relationship with and understanding of wildfire smoke, use of strategies for protecting one's health from smoke, and experience with prescribed burns (Supplement S2 in the online supplement). The interview guide was developed by LCM with edits from CML and KAD and expert guidance from AA.

### ***Participant Recruitment***

Potentially eligible participants were initially identified using electronic health record data (Supplement S3 in the online supplement). Patients were eligible if they met 3 criteria:

1. Received COPD as an International Classification of Disease-10th edition coded diagnosis (J44.1, J44.0, J41.8, J44.9, J42) between 9/30/2021–10/31/2024 during either at least 1 hospitalization or at least 2 outpatient encounters;
2. Were  $\geq 65$  years old;
3. Had an active Kaiser membership as of 10/31/2024.

We further narrowed to those with a neighborhood deprivation index (NDI)<sup>19</sup> in the highest quartile in order to focus on those with low socioeconomic status. The diagnosis code definition of COPD produces sensitivity (69.2%) and specificity (93.2%).<sup>20</sup> The rationale for recruiting those  $\geq 65$  years old was to enrich for patients with COPD (versus asthma), to interview patients with enough lived experience over time with smoke from any source, and to interview patients who would ultimately be the target population of an intervention (patients aged >65 years spend >80% of time at home where you would deliver a home intervention, such as air cleaners).<sup>21,22</sup>

We excluded patients who could not speak English,

were enrolled in hospice, had a tracheostomy, or did not have a mailing address (presumably undomiciled). We emailed patients' primary care physicians to further identify anyone who should not be contacted for recruitment due to issues not readily identified above.

To stagger enrollment, we proportionally divided the list into 3 equally sized groups with the same distribution of zip codes. The first group received an information packet mailed to their homes. Because recruitment proceeded quickly, saturation was reached before further mailings were needed.

### **Conducting the Interviews**

An internal medicine trained male physician (JY), a Master of Public Health student at the time, conducted the interviews. JY received both formal (UC Berkeley) and informal training (mentorship at Kaiser Permanente Northern California Division of Research) in qualitative methods. Verbal consent was obtained over the phone prior to initiating the interview. Interviews lasted ~30 minutes and were conducted securely via Microsoft Teams, utilizing embedded voice-to-text transcription. Interviews were scheduled until the point of thematic saturation, when repeated themes emerged with each additional interview.<sup>23</sup> Field notes were written after each interview by LCM upon listening to the recordings. The output files were deidentified and loaded into standard qualitative interview software (Dedoose 10.0.25; Los Angeles, California). Participants did not provide feedback on the interview transcripts or themes.

### **Qualitative Analysis**

We performed traditional thematic analysis through the iterative process of analyzing patterns in qualitative data. We took both inductive and deductive approaches. Initially, an inductive approach was utilized where themes emerging from participants' responses were collected into a codebook. The codebook was drafted by JY, modified by CML and LCM using the first 5 interviews, and revised by expert AA (Supplement S4 in the online supplement). The team ensured that the coding structure reflected the lived experiences and perspectives of participants. Once the codebook was agreed upon, JY manually coded the remaining interview transcripts for recurring themes and categories. Meanings were considered primarily at the explicit level but with consideration of implicit interpretations. Illustrative quotes were flagged. To make the findings as practical as possible, we provide examples of practical insights into how an intervention could be designed based on the barriers and facilitators elicited during the interviews.

## **Results**

### **Description of Participants and Their Relationship With Smoke**

Of 90,696 adults aged  $\geq 65$  years with COPD, 6338 met all inclusion/exclusion criteria (full details in Supplement S3 in the online supplement). Of the 2112 patients who received the initial recruitment packet in the mail, 180 patients contacted us, of whom 107 stated they were potentially interested. We scheduled interviews between 1/7/2025–1/21/2025 in the order in which people expressed interest.

The demographic characteristics of the 31 participants are listed in Table 1. The average age was 75 years old (standard deviation [SD] 6.3). Eighteen participants (58%) were female. Average NDI was 0.9 (SD 0.7). Participant's self-identified race/ethnicity was 19% Black, 10% Hispanic, 3% Native American, and 68% non-Hispanic White. Individuals lived in 10 counties across Northern California: Alameda, Contra Costa, San Mateo, Sonoma, Stanislaus, Solano, Madera, San Joaquin, Sacramento, and Fresno. Nearly all ( $n=28$ , 90%) interviewees had some form of cigarette/cigar smoking history, and 4 (13%) identified as current smokers. Most interviewees ( $n=28$ , 90%) denied having to evacuate their homes for a past wildfire. One participant reported working as a firefighter previously.

Participants described neutral or even positive experiences of smoke exposure from fireplaces and campfires but described negative experiences toward cigarette/cigar smoke, wildfires, or structural fires. Most participants stated that they believed their health has been more impacted from repeated exposure to smoke over time, especially cigarette smoke, rather than a 1-time exposure, such as a wildfire. When asked which organ(s) are affected by smoke, few named  $>1$  organ beyond the lungs. They reported feeling more concern about smoke exposure later in life due to instances when smoke has triggered respiratory symptoms (e.g., shortness of breath, chest tightness). Despite concerns about smoke, nearly all of participants stated they supported the use of prescribed burns because the public could be made aware of the smoke ahead of time and such prescribed burns could offset the risk of larger wildfires. Most participants stated that they were not regularly thinking about wildfire smoke (e.g., on a week-to-week basis) unless there was a wildfire event in the news.

### **Major Themes Elicited**

Table 2 depicts the major themes, which are described below with illustrative quotes.

#### Theme 1

Patients tend to get information about poor air quality from the internet and smartphone apps, and not from clinical interactions, but they would be open to

**Table 1. Participant Demographics**

| Variables                                   | Participants (n=31) |
|---|---------------------|
| <b>Age</b>                                  |                     |
| Mean (SD)                                   | 75 (6.3)            |
| Range                                       | 66 – 89             |
| <b>Sex</b>                                  |                     |
| Female                                      | 18 (58%)            |
| Male  | 13 (42%)            |
| <b>NDI</b>                                  |                     |
| Mean (SD)                                   | 0.9 (0.7)           |
| Range                                       | -0.1 to 3.3         |
| <b>Race/Ethnicity</b>                       |                     |
| Black                                       | 6 (19%)             |
| Hispanic/Latino                             | 3 (10%)             |
| Native American                             | 1 (3%)              |
| Non-Hispanic White                          | 21 (68%)            |
| <b>Smoking Status</b>                       |                     |
| Current Everyday Smoker                     | 3 (10%)             |
| Current “Some Days” Smoker                  | 1 (3%)              |
| Former Smoker                               | 24 (77%)            |
| Never Smoker                                | 3 (10%)             |
| <b>Previously Evacuated Due to Wildfire</b> |                     |
| Yes   | 3 (10%)             |
| No  | 28 (90%)            |

SD=standard deviation

receiving the information from clinicians/health care entities.

People got their information from a variety of sources, predominantly the internet and smartphone apps, but also television, newspaper, and other community members. One participant said they received air quality information from “*the news on the Internet. I Google and check to see what's going on as far as the weather and the air conditions.*” Another stated, “*I don't have [my own] TV and I don't have radio...I hear it from other people. Sometimes I go downstairs in the community room, watch the news, and I see it.*” Some used Air Quality Index or other weather monitoring applications on their smartphones. One participant stated, “*I have a weather app...and it'll give me the air index quality at that time. Sometimes when it seems like a perfectly normal day out there, air index quality is pretty high, meaning it's unhealthy.*” Very few had ever gotten information from their clinicians, but almost all would be open to receiving the information from them regarding poor air quality events. Additionally, very few knew about or owned low-cost sensors but would be open to the idea of monitoring local air quality in and around their homes.

### Theme 2

There appear to be some modifiable barriers of uptake of mitigation strategies to reduce exposure to wildfire smoke, such as education and supplying the equipment (e.g., air cleaners, masks).

The top reasons people would not go outside included smell or sight of smoke or an alert from a local health or environmental agency. One participant described their thought process in terms of deciding whether to go outside, “*The alerts you get might be...25 miles away from you, but then [smoke] blows into your zip code. If I see it or smell it or the sky is orange...I'm not going out.*” While some people felt confident that they knew when air quality was at a level that was harmful to health, not everyone did. When asked if the color of the sky, smell of smoke, or alert message would cause them to not go outside, one participant admitted, “*I'd still go out because I wouldn't even think about what you just mentioned... I've done it. I didn't know you weren't supposed to.*” There was significant variation in when and how people decided that air quality was bad enough to modify their behavior.

Many of the barriers of uptake of mitigation strategies were modifiable through education or direct provision of equipment. In terms of knowledge of specific mitigation strategies, some people knew about and used the vehicle recirculation button but not all, and some actively chose not to use it. Someone explained, “*I'm a fresh air person. I keep my windows open and I just don't care.*” Some wore masks when going outside during periods of poor air quality, but others did not because they found them uncomfortable or associated them with the COVID-19 pandemic. Many expressed interest in and desire for portable air cleaners but cited finances as the main barrier, “*I wish I did [have an*

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**Table 2. Themes Elicited from Participants With COPD About Protecting One's Health from Wildfire Smoke**

| Theme  | Details  | Illustrative Quotes   |
|--|--|---|
| <b>Theme 1</b><br><br>Patients tend to get information about poor air quality from the internet and smartphone apps, and not from clinical interactions, but they would be open to receiving the information from clinicians/health care entities. | People get information from a variety of sources, predominantly the internet and smartphone apps, but also television, newspaper, and other community members.   | <p>"On the news on the Internet. I Google and check to see what's going on as far as the weather and the air conditions. And also I get alerts about different stuff."</p> <p>"I don't know that I'm subscribed to an alert system, but somehow somehow I did get some information on that Napa fire in my phone and I don't know how that happened."</p> <p>"I don't have [my own] TV and I don't have radio, so I don't hear it there. I hear it from other people. Sometimes I go downstairs in the community room, watch the news, and I see it. But normally I know when I start walking and I'm coughing, so that can be my first sign."</p> <p>"Well, you know, I get the newspaper 7 days a week. I know a lot of people do the Internet. I don't do the Internet and then I have my husband here who is very informative."</p>   |
|  | Some use Air Quality Index or AirNow and other weather monitoring applications on their smartphones.   | "I have a weather app that I can pull up...and it'll give me the air index quality at that time. Sometimes when it seems like a perfectly normal day out there, air index quality is pretty high, meaning it's unhealthy."  |
|  | Very few have ever gotten information from their clinicians, but almost all would be open to receiving the information from them regarding poor air quality events.  | <p>"I could call my doctor and she might know that information [about air quality]."</p> <p>"Kaiser is real good about sending out notices [about things]...I tell people to go to the website and look and it'll tell you what to do...But yeah, we pretty much stick to the news on television [about air quality]. And also the state provided information, you know CalFire."</p>   |
|  | People tend to be more vigilant regarding the effects of wildfires and smoke if there is an active wildfire in the news, especially if in their vicinity and their family alerts them.   | <p>"[A wildfire] would be on the radio or on the TV and I'd be more aware of it, more concerned about it."</p> <p>"Yes, [my sister] tells me, 'Sis, there's a there's fire going on around you. Stay inside the house.'"</p> <p>"If there was a wildfire in the area... that would tell me to keep myself in the house and just, you know, exercise in place as opposed to outside. No exertion outside and that kind of a situation."</p>  |
|  | Very few know about or own low-cost sensors but people would be open to the idea of monitoring air quality in and around their home.   | <p>"I've never heard of those [sensors]."</p> <p>"I would like one of those [sensors], but I cannot afford one of those."</p>   |
| <b>Theme 2</b><br><br>There appear to be some modifiable barriers of uptake of mitigation strategies to reduce exposure to wildfire smoke, such as education and supplying the equipment (e.g., air cleaners, masks).                              | The top reasons people would not go outside include smell or sight of smoke or an alert from a local health or environmental agency.   | <p>"The alerts you get might be...25 miles away from you, but then [smoke] blows into your zip code. If I see it or smell it or the sky is orange...I'm not going out."</p> <p>"If it's orange outside, I don't wanna go out. I'll look to see when there's a lightening of the smoke level and go out to the mailbox and pick it up 'cause we do have our mailboxes at the curb, so I do have to go out to get it. And if I go out, I wear a mask, N95."</p> <p>"You know, I would certainly accept information from a government agency, one of the local, like the county or the city."</p> <p>"They need to let me know the air quality ahead of time. Can I go outside or do I stay inside?"</p> <p>"Yes, [I subscribe to an app] and it's free. It's put out by the Air Quality district... I'm also on a list for California wildfire and they will send out emergency announcements as well. And the [County] will also do it, so I get it from a number of different sources. And I take it seriously."</p>  |
|  | Some people know not to go outside during periods of poor air quality but not all. There was significant variation across people in terms of when and how people decided that air quality was bad enough to modify their behavior. | <p>"No, those are the times I stay indoors. I do not go outside. I stay indoors in the filtered air. I got a great filter system on the house."</p> <p>"Once again, yeah, stay indoors. Keep the doors closed and, you know, the windows shut. I don't run my ceiling fans... My HVAC system will be on... And that's on re-circulation."</p> <p>"It might have to do with visibility 'cause if, like I could hardly see the mailbox out on the street, I might not wanna go outside. But if I could kinda still see it and could move quickly, get through it, [and] back in the house, I might be OK with [going outside]"</p> <p>When asked if the color of the sky, smell of smoke, or alert message would cause them to not go outside: "I'd still go out because I wouldn't even think about what you just mentioned... Right, I've done it. I didn't know you weren't supposed to."</p> <p>"I can be very [stubborn] about getting my walks in. And [my wife] would say, you know, stay in and work and ride the stationary bike... And that would be a borderline. If the smoke was really bad, nobody's gotta tell me 'don't go out.'... You know, if it's on the edge, it's just better off that you don't go out."</p> |
|  | Some people know about and use the vehicle recirculation button but not all, and some actively choose not to use it.   | <p>"I know we had the big fires here a couple of years ago that forced me to stay indoors. I was much more comfortable indoors and when I did go out and about, I was able to use the recirculation in my automobile"</p> <p>"I'm a fresh air person. I keep my windows open and I just don't care."</p>  |
|  | Some wear masks when going outside during periods of poor air quality, but others do not because they find them uncomfortable or associate them with the COVID-19 pandemic.  | <p>"I try to wear a mask but it does affect me with breathing and it's not a good feeling... You know you don't walk as fast because you have [a mask on]. I'm actually out of breath."</p> <p>"Not since COVID have I worn a mask other than when I've had a cold or been sick, and I was going out around people. I haven't because of the air quality. The answer's no."</p> <p>"If I do have to go out [when the air is bad], let's say to go grocery shopping or something, I will at that point wear a mask. I mean, this has nothing to do with COVID. Just because the air is so bad, I wear a mask."</p>   |
|  | Many want portable air cleaners but cannot afford them.  | <p>"I wish I did [have an air cleaner]. But I don't... I live on \$1500 a month. That's it. That's all I live on."</p> <p>"When I told [my daughter] that I was using more inhalers during the wildfires, she went and bought the air purifiers and she said, 'Mom, whatever you do, don't go outside. Just stay in the house.'"</p>  |
|  | Some ensure their living places had tight sealing of windows and doors, but many felt as though they could not modify their living place if they were renting out of fear of being dismissed by the landlord.                      | <p>"As a matter of fact, we have good weather sealing. We had PG&amp;E come in. We did the whole house."</p> <p>"My windows and doors are a mess...My husband basically boarded up everything because the cold air comes through the windows... and I want to talk to a landlord about getting some new windows and stuff, but I'm skeptical of that because once they do stuff then they go up on your rent. So don't want to rock the boat."</p> <p>"A lot of air comes through the window. I live in... public housing, so it's like the projects you might say, I pay 30% of the rent, and the federal government and state pay the rest. And so you kind of get what you get in this particular building. And you don't have any weather stripping...it's just like you're on your own."</p>   |

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|  |   |   |
|--|---|---|
|  | <p>Some know to change or clean the filter in HVAC system but not all. Among those who commonly changed the filters, they often cited getting help from family members.</p>   | <p>"I got a couple of [filters] in there and when the time is right in February now it'll be time to change the filter again."<br/>                 "The person who owns the house has the HVAC system regularly serviced, so I don't know anything about that."<br/>                 "I have a filter that [the landlords] don't [check]. They haven't yet since I've been here for 4 years. I've been complaining to them about that. But sometimes we'll take the filter out and clean it ourselves, you know? Run it through the water and then put it back in."<br/>                 "My son had to take it down and clean [the filter] out. They were supposed to give out brand new ones, for everybody, every year. But they did not do it this year, so my son took mine down and cleaned it out and put it back in."</p>  |
| <p><b>Theme 3</b><br/>                 Patients prefer real-time alerts directly to their phones coming from trusted sources, such as their clinicians (or health care entities more broadly) in collaboration with government agencies in order to be most likely to change their behavior during periods of forecasted poor air quality.</p> | <p>Alerts would preferably come from a trusted health care entity, potentially in collaboration with a government agency (e.g., the county).<br/>                 Patients preferred alerts about poor air quality over the next ~1–2 days coming directly to their phones.<br/>                 Some want their health care organization to go beyond air quality alerts in the event of a wildfire, including helping with evacuation and/or re-location information.<br/>                 Informational packets at the beginning of wildfire season would be acceptable, but patients didn't think that would be extremely helpful compared to other interventions, such as equipment or real-time alerts.</p> | <p>"You know, it's just another e-mail unless it comes from my doctor. If there's a quality of the air problem [according to my doctor], all of a sudden I'm going to be very aware of it and keep my eyes open...I would say if Kaiser did something like that... that would be beneficial."<br/>                 "I check every message that I get from my doctor."<br/>                 "If I get a message from the county alert system and then I see I've got other alerts coming in that all start with wildfire, smoke or smog, I don't open all of them."<br/>                 "Myself, I go by day-to-day, so like 24 hours. I need to know what I'm looking at in the next day, if possible."<br/>                 "In the next 48 hours, just so I can plan ahead...I don't always carry my inhaler with me, which is a bad thing...if it's going to be bad somewhere where I'm going, like for a walk...it's helpful to know what to take with me."<br/>                 "There's 2 things that Kaiser could do...it could send out a warning to those areas that are going to be heavily contaminated, for people to stay inside. And above that, there are people who are not as lucky as my family. Will we have some place where we can shelter in place? And there are areas within the hospitals where they could possibly arrange to have people go in an emergency...Even if it's not at the hospital, directing them to other locations where people can shelter."<br/>                 "OK but I think it's more like, making sure that I have the right equipment in addition to the pamphlet or alert...Those kinds of things go together."<br/>                 "I like the pamphlets and information but also the mask and purifiers. You know, buying in quantity, they're less expensive."</p> |

air cleaner]. But I don't...I live on \$1500 a month. That's it. That's all I live on." Some ensured their living places had tight sealing of windows and doors, but many felt they could not modify their living place if they rented out of fear of being evicted by the landlord. One participant explained, "A lot of air comes through the window. I live in...public housing, it's like the projects you might say... you kind of get what you get in this particular building. You don't have any weather stripping...it's just like you're on your own." Another said, "My windows and doors are a mess...My husband basically boarded up everything because the cold air comes through the windows... I want to talk to a landlord about getting some new windows and stuff, but I'm skeptical of that because once they do stuff then they go up your rent. Don't want to rock the boat." Lastly, some knew to change or clean the filter in HVAC system but not all. Among those who commonly changed the filters, they often cited getting help from family members.

Theme 3

Patients prefer real-time alerts directly to their phones coming from trusted sources, such as their clinicians (or health care entities more broadly) in collaboration with government agencies, to be most likely to change their behavior during periods of forecasted poor air quality.

Patients overwhelmingly expressed trust in their clinicians or health care entities with one participant saying, "You know, it's just another e-mail unless it comes from my doctor. If there's a quality of the air problem [according to my doctor], all of a sudden I'm going to be very aware of it and keep my eyes open." Another said, "I check every message that I get from my doctor." Many expressed similar views,

stating that they'd be more likely to modify their behavior if the alert came from a health care entity that knew them and their medical history, potentially in collaboration with a government agency.

When asked about what type of alerts were preferred, participants overwhelmingly endorsed forecasted air quality alerts for the next 1–2 days coming directly to their phones. One endorsed, "In the next 48 hours, just so I can plan ahead...I don't always carry my inhaler with me, which is a bad thing...if it's going to be bad somewhere where I'm going, like for a walk...it's helpful to know what to take with me." In addition to alerts about air quality, several mentioned wanting to hear information about emergency evacuation and relocation. One suggested, "There are areas within the hospitals where they could possibly arrange to have people go in an emergency...Even if it's not at the hospital, directing them to other locations where people can shelter."

**Turning the Barriers and Facilitators into Practical Insights for Designing an Intervention**

We provide several examples of how the barriers and facilitators elicited during the qualitative interviews provide practical information for designing future interventions (Table 3). For example, an air quality alert intervention where alerts are tailored to patients' medical history and come from a trusted health care entity would overcome the barrier of patients not knowing when to modify their behavior and leverage the facilitator of trusting their health care system to advise on their health. Alternatively, a home intervention where education and equipment are brought directly to patients' homes, potentially with engagement of family members during the home visit, would overcome the barriers of lack of knowledge and financial concerns about

**Table 3. Gaining Practical Insights Into How to Design an Intervention to Limit Patients' Exposure to Wildfire Smoke Based on the Barriers and Facilitators Elicited**

|   | Practical Implications for Designing an Intervention   |
|---|--|
| <b>Examples of Barriers</b>   |  |
| Lack of understanding that air quality can be harmful to health in high-risk patient populations like COPD at levels that cannot be detected by sight/smell | Tailor air quality alerts to patients' medical history so they can modify their lifestyle appropriately according to their true risk, rather than sifting through general public health guidance that may not be relevant to them.   |
| Financial concerns of obtaining equipment (e.g., portable air cleaners)   | Deliver portable air cleaner equipment directly to patients' homes with no/minimal cost and assist with ways to maintain electricity to the unit; advocate for policy change that would require air cleaners be covered as durable medical equipment for high-risk patients living in areas that are prone to wildfire smoke; provide public clean air spaces more widely. |
| Mask discomfort or association with COVID-19 rather than with protection from smoke   | Provide N95 masks and free fittings along with education about why/when they are necessary to use outdoors during periods of poor air quality; raise public health awareness so it is more mainstream to see people wearing masks to protect themselves from smoke.  |
| Not using vehicle air recirculation due to wanting "fresh air"  | Educate patients about the harms of smoke even when they cannot see/smell it.  |
| Fear of increased rent or eviction for requesting weather stripping or HVAC filter changes/installations in rented spaces                                   | Provide home services that are free and fully in accordance with tenant contracts; explore tenants' legal rights to request reasonable changes to the dwelling place; advocate for regulatory standards for indoor air quality in public housing.  |
| <b>Examples of Facilitators</b>   |  |
| Trust in health care entity to advise on when patients should modify their behavior   | Pre-emptively counsel patients during clinic visits about how to modify their behavior during periods of poor air quality; health care entities can be the source of air quality alerts.   |
| Help and support from family, friends, and community members  | Encourage involvement of trusted people to help in heeding warnings to modify behavior, restructuring the home environment, and utilizing available resources/programs to mitigate exposure to smoke as much as possible.  |

COPD=chronic obstructive pulmonary disease

obtaining equipment, as well as leverage the help of family to support vulnerable patients during periods of poor air quality.

## Discussion

Among COPD patients with low socioeconomic status, we utilized a qualitative approach to understand patients' perspectives about the ways they protect their health in the setting of poor air quality events, including the barriers and facilitators related to uptake of mitigation strategies that reduce wildfire smoke exposure. While we anticipated hearing about financial barriers to obtain equipment, we uncovered several key insights, such as how rare it was that patients had received information from clinicians about the health risks of smoke, the degree of trust that patients put in health care entities to advise them on when to modify their behavior in relation to smoke, the fear of losing access to rented housing if they were to ask the landlord for weather stripping or air filter changes, and the important role of family/community members to help this vulnerable patient population modify their homes or individual behaviors. Health-promoting behavioral interventions have been shown to be more effective when multidisciplinary community support organizations come together<sup>24</sup> (in this case, it would potentially be health system and public health through the county/state).

While there is extensive quantitative research documenting the epidemiologic associations between concentrations of particulate matter air pollution and poor health outcomes,<sup>1,5</sup> there is less qualitative information to help guide the design and deployment of interventions, which is the important gap that this study fills. Studies done across the world in settings prone to wildfires have found broad themes similar to us, such as need for education, provision

of equipment, and accurate, real-time information.<sup>11,25-29</sup> Our study extends the existing qualitative literature about how high-risk patients (older COPD patients with low socioeconomic status) can protect themselves from the growing health threat of wildfire smoke and what health systems can do to protect the most vulnerable. Our focus on low socioeconomic status provides unique insights into social barriers, such as legal and financial interactions with landlords. Eliciting the patients' points of view provides insights into their social and behavioral context that are critical when planning a community-based or public health intervention.<sup>30</sup> The 3 most relevant existing studies are summarized here:

1. Seale et al conducted 20 interviews with people with obstructive lung disease living in bushfire-prone regions of Australia to ask specifically about barriers to mask use during wildfire events. They revealed knowledge as the primary barrier, despite masks being widely used during the pandemic, and called for better communication from experts about why, how, and when to use masks during wildfire events.<sup>28</sup> Our findings were broader and focused on other interventions besides masks.
2. Hoshiko et al from the Department of Public Health conducted a cross-sectional survey of 106 medically-vulnerable people living in a rural county in California. While respondents reported taking on average 5 "actions" to reduce smoke exposure, such as wearing a mask, turning on an air cleaner, changing their daily activity, and using additional medications, approximately half (47%) reported lacking confidence in how to successfully protect their health from smoke.<sup>29</sup> We interviewed a more geographically diverse patient population compared to Hoshiko et al but have some of the same findings.

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- Humphreys et al performed focus groups with residents and key informant interviews with local health/social service staff in Washington state. They reported the need for training health care workers to communicate effectively to the public, forming critical links between scientific/health care organizations and the public for accurate communication about health risk, and prosocial interactions among community members and organizations to prepare for and manage the aftermath of wildfire events.<sup>11</sup> We performed individual interviews instead of focus groups, but some of the same themes emerged.

There are several notable strengths and limitations of our study. We leveraged the Kaiser Permanente integrated health network located near historically large wildfires. We recruited diverse patients, in terms of race/ethnicity and geography, as well as patients who had a vast range of experience regarding wildfire smoke exposure. The Kaiser Permanente Northern California member population is similar in demographic characteristics compared to the background population in Northern California, which speaks to the generalizability of the findings.<sup>31</sup> However, patients who participate in the Kaiser Permanente health plan may have more trust in their health system, given that the organization typically retains 80%–90% of its members with COPD over a 5-year period. Thus, their views may differ from the general population in terms of the extent to which they wish to be contacted by their clinician or health plan. We were able to recruit participants extremely quickly (<1 month) without “cold calling” people, which is likely owed to the broad effort we made in mailing >2000 packets but could also suggest enrichment for participants who are interested or knowledgeable about the topic, such as the retired firefighter. Due to funding limitations, we could only include English speakers.<sup>32</sup> We were not able to extract pulmonary function data to confirm airway flow limitation.

## Conclusion

This study fills a critical translation gap identified by the American Thoracic Society and National Institutes of Health<sup>15,33</sup> by eliciting insights directly from high-risk patients. This study identifies several important themes that can be used to design successful interventions that will promote uptake of wildfire smoke exposure mitigation strategies. As we grapple with climate change, this information can be used by health care systems, public health entities, and clinicians to lead interventions, educational efforts, and policy reforms that improve wildfire smoke preparedness for high-risk patients. Clinicians can utilize this information and potentially address the risks of poor air quality in high-risk patients in clinic, which has not traditionally been addressed by clinicians at office visits.

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**Author contributions:** NH, MD, and LCM conceived the idea and LCM obtained funding for the study. CML, KAD, MM, SA, AA, and LCM contributed to the design of the study. CML and KAD prepared study materials, coordinated International Review Board submission and weekly progress meetings where critical decisions were made relative to study design, and prepared the manuscript for submission. NP contributed to the production of the eligible patient dataset. JY collected and analyzed the data under guidance from LCM, with input from CML and AA. JY drafted the first version of the manuscript. All authors contributed to the interpretation of the data and the revising and approval of the manuscript.

## Declaration of Interest

The authors declare that they have no competing interests.

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