Original Research

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

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***Running Head*: COPD Patient Perspectives, Wildfire Smoke Exposure**

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***Abbreviations*:** COPD=chronic obstructive pulmonary disease; ICD-10=International Classification of Diseases, Tenth Revision; NDI=neighborhood deprivation index; SD=standard deviation

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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' point of view about barriers and facilitators of strategy uptake.

Methods: We performed semi-structured, virtual interviews with members of Kaiser Permanente Northern California until thematic saturation. We recruited participants aged ≥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 appear to be modifiable barriers to uptake of mitigation strategies, such as education and supplying equipment (e.g., masks, air cleaners), and 3) patients prefer real-time alerts sent to their phones from trusted sources, such as healthcare entities, to change their behavior during periods of poor air quality.

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

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Introduction

Long-term exposure to wildfire smoke is associated with increased mortality[1]. As a direct result of climate change, wildfire smoke is responsible for a growing fraction of particulate matter air pollution in the United States[2]. 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[3,4]. Existing literature supports a dose response relationship with one study reporting a 2.7% increase in COPD exacerbations for every 10µg/m^3 rise in particulate matter exposure[5,6]. Although people living on the West Coast are considered to be at highest risk of exposure to wildfire smoke, smoke originating in the West Coast travels east with the jet stream, putting the entire country at risk[7,8].

The health burden of wildfire smoke falls disproportionately on vulnerable populations, especially those with low socioeconomic status[9-11]. 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[12-14]. 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[9].

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 (HEPA) cleaners[15]. These mitigation strategies are recommended by the Environmental Protection Agency and Centers for Disease Control and

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Prevention[16,17]. 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[18], studies have shown limited uptake of portable air cleaners (and other mitigation strategies)[12].

In this study, we performed qualitative interviews with patients aged ≥65 years old with COPD and low socioeconomic status, who live 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 harms 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, semi-structured 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 healthcare provider. **Supplement S1** contains the 32-item checklist for the Consolidated Criteria for Reporting Qualitative Studies.

Developing the Interview Guide

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We developed an interview guide at a ≤5th 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**). 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**). Patients were eligible if they met three criteria: 1) COPD as an International Classification of Disease (ICD)-10 coded diagnosis (J44.1, J44.0, J41.8, J44.9, J42) between 9/30/2021-10/31/2024 during either a) at least 1 hospitalization or b) at least 2 outpatient encounters, 2) ≥65 years old, and 3) active Kaiser membership as of 10/31/2024. We further narrowed to those with a neighborhood deprivation index (NDI)[19] 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%)[20]. The rationale for recruiting those ≥65 years old was 1) to enrich for patients with COPD (versus asthma), 2) to interview patients with enough lived experience over time with smoke from any source and 3) 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)[21,22].

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 three equally sized groups with the same distribution of zip codes. The first group received an information packet mailed to

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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[23]. 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). 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**). 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

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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 ≥65 years with COPD, 6,338 met all inclusion/exclusion criteria (full details in **Supplement S3**). Of the 2,112 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**. Average age was 75 years old (Standard Deviation (SD) 6.3). Eighteen participants (58%) were female. Average NDI was 0.9 (SD 0.7). Self-identified race/ethnicity was 19% Black, 10% Hispanic, 3% Native American, and 68% non-Hispanic White. Participants 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; 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,

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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 one-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 support the use of prescribed burns because the public can be made aware of the smoke ahead of time and such prescribed burns can 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 receiving the information from clinicians/healthcare entities.

People get information from a variety of sources, predominantly the internet and smartphone apps, but also television, newspaper and other community members. One participant said he/she 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 use Air Quality Index or other weather monitoring applications on their smartphones. One participant stated, *"I have a*

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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 have 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 know about or own low-cost sensors (e.g. Purple Air) but people 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 include 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 know about and use the vehicle recirculation button but not all, and some actively choose not to use it. Someone explained, *"I'm a fresh air person. I keep my windows open and I just*

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don't care." 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. Many expressed interest in and desire for portable air cleaners but finances as the main barrier, *"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."* Some ensure their living places have tight sealing of windows and doors, but many feel they cannot modify their living place if they rent 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 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.

Theme 3: Patients prefer real-time alerts directly to their phones coming from trusted sources, such as their clinicians (or healthcare 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 healthcare 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

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alert came from a healthcare entity that knows 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 re-location. 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 healthcare entity would overcome the barrier of patients not knowing when to modify their behavior and leverage the facilitator of trusting their healthcare 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 obtaining equipment, as well as leverage the help of family to support vulnerable patients during periods of poor air quality.

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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 healthcare 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[24] (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[1,5], 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[11,25-29]. 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

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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' point of view provides insights into their social and behavioral context that are critical when planning a community-based or public health intervention[30]. 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[28]. 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, using additional medications, approximately half (47%) reported lacking confidence in how to successfully protect their health from smoke[11]. We interviewed a more geographically diverse patient population compared to Hoshiko et al but have some of the same findings. 3) 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 healthcare workers to communicate effectively to the public, forming critical links between scientific/healthcare 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[11]. We performed individual interviews instead of focus groups but some of the same themes emerged.

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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[31]. 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 >2,000 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[32]. 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[15,33] 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

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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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Table 1: Participant Demographics

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

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Table 2: Themes elicited from participants with COPD about protecting one's health from wildfire smoke

Theme	Details	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 receiving the information from clinicians/healthcare entities.	People get information from a variety of sources, predominantly the internet and smartphone apps, but also television, newspaper and other community members.	*"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."* *"I don't know that I'm subscribed to an alert system, but somehow someway I did get some information on that Napa fire in my phone and I don't know how that happened."* *"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."* *"Well, you know, I get the newspaper seven 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."*
	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.	*"I could call my doctor and she might know that information [about air quality]."* *"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."*
	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.	*"[A wildfire] would be on the radio or on the TV and I'd be more aware of it, more concerned about it."* *"Yes, [my sister] tells me, 'Sis, there's a there's fire going on around you. Stay inside the house.'"*

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Theme	Details	Illustrative Quotes
		"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."
	Very few know about or own low-cost sensors (e.g. Purple Air) but people would be open to the idea of monitoring air quality in and around their home.	*"I've never heard of those [sensors]."* *"I would like one of those [sensors], but I cannot afford one of those."*
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 include smell or sight of smoke or an alert from a local health or environmental agency.	*"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."* *"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."* *"You know, I would certainly accept information from a government agency, one of the local, like the county or the city."* *"They need to let me know the air quality ahead of time. Can I go outside or do I stay inside?"* *"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."*

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Theme	Details	Illustrative Quotes
	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.	"*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.*" "*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.*" *"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]"* *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."* *"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."*
	Some people know about and use the vehicle recirculation button but not all, and some actively choose not to use it.	*"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"* *"I'm a fresh air person. I keep my windows open and I just don't care."*
	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.	"*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.*" *"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."* *"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."*

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Theme	Details	Illustrative Quotes
	Many want portable air cleaners but cannot afford them.	*"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."* *"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.'"*
	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.	*"As a matter of fact, we have good weather sealing. We had PG&E come in. We did the whole house."* *"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."* *"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."*
	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.	*"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."* *"The person who owns the house has the HVAC system regularly serviced, so I don't know anything about that."* *"I have a filter that [the landlords] don't [check]. They haven't yet since I've been here for four 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."* *"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."*

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Theme	Details	Illustrative Quotes
Theme 3 Patients prefer real-time alerts directly to their phones coming from trusted sources, such as their clinicians (or healthcare 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.	Alerts would preferably come from a trusted healthcare entity, potentially in collaboration with a government agency (e.g. the county).	*"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."* *"I check every message that I get from my doctor."* *"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."*
	Patients preferred alerts about poor air quality over the next ~1-2 days coming directly to their phones.	"*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."* *"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."*
	Some want their healthcare organization to go beyond air quality alerts in the event of a wildfire, including helping with evacuation and/or re-location information.	*"There's two 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."*
	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.	*"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."* *"I like the pamphlets and information but also the mask and purifiers. You know, buying in quantity, they're less expensive."*

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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
Examples of Barriers	
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
Examples of Facilitators	
Trust in healthcare 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; Healthcare entities can be the source of air quality alerts

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	Practical implications for designing an intervention
Help and support from family, friends and community members	Encourage involvement of trusted people to help in heeding warnings to modify behavior, re-structuring the home environment and utilizing available resources/programs to mitigate exposure to smoke as much as possible

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Online Supplement

Understanding COPD patients' perspectives on how to protect their health from wildfire smoke

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Supplementary Material S1: Consolidated Criteria for Reporting Qualitative Studies (COREQ) 32-item checklist
Supplementary Material S2: Participant Interview Guide/Script
Supplementary Material S3: Flow Diagram of Eligibility List
Supplementary Material S4: Qualitative Analysis Code Book

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Supplementary Material S1. Consolidated Criteria for Reporting Qualitative Studies (COREQ) 32-item checklist

No. Item	Guide questions	Description
Domain 1: Research team and reflexivity		
Personal Characteristics		
1. Interviewer/ facilitator	Which author/s conducted the interview or focus group?	Interviews were conducted by 1 trained physician interviewer (J.Y.)
2. Credentials	What were the researcher's credentials? E.g. PhD, MD	The interviewer had a medical degree and in progress of an MPH degree (J.Y.)
3. Occupation	What was their occupation at the time of the study?	The interviewer was a medical doctoral resident and MPH student (J.Y.)
4. Gender	Was the researcher male or female?	Interviewer was male (J.Y.)
5. Experience and training	What experience or training did the researcher have?	J.Y. had prior experience working with patients as a resident and prior research related experience from his time in medical school and during clinical rotations. J.Y. worked closely with Project PI (L.C.M), qualitative research expert and mentor (A.A.), and the rest of the research team (C.M.L., S.A., K.A.D.) for training in conducting qualitative interviews. Additionally, J.Y. conducted three mock interviews with members of the research team prior to the first patient interview in order to receive feedback and familiarize himself the interview guide. The team members in mock interviews were not familiar with the interview guide prior.

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No. Item	Guide questions	Description
Relationship with participants		
6. Relationship established	Was a relationship established prior to study commencement?	No interviewers had pre-existing relationships with participants.
7. Participant knowledge of the interviewer	What did the participants know about the researcher? e.g. personal goals, reasons for doing the research	Participants had no prior knowledge regarding the interviewer. Upon recruitment, interviewer identified himself as a resident physician and a member of the research team (J.Y.).
8. Interviewer characteristics	What characteristics were reported about the interviewer/ facilitator? e.g. Bias, assumptions, reasons and interests in the research topic	The interviewer (J.Y.) is a medical resident currently in progress of a MPH with research interest in social determinants of health, including socioeconomic status, racial/ethnic, and sex-based disparities in health outcomes, as well as environmental health/medicine and occupational exposures. As an internist, he is trained in the art of asking open-ended questions and active listening. He has undergone training to limit bias in interaction with patients.
Domain 2: Study design		
Theoretical framework		
9. Methodological orientation and Theory	What methodological orientation was stated to underpin the study? e.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis	We performed traditional thematic analysis through the iterative process of analyzing patterns in qualitative data, utilizing both inductive and deductive approaches (Miles and Huberman, Qualitative Data Analysis, 1994).

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No. Item	Guide questions	Description
Participant selection		
10. Sampling	How were participants selected? e.g. purposive, convenience, consecutive, snowball	We generated a list of eligible patients with COPD who were aged >/=65 years. We did not require that patients live near a previous wildfire event or have direct experience/exposure with wildfire smoke. Patients were randomly sorted into three mailing groups based on a weighted distribution of their zip code in order to ensure geographic diversity. Strata were used to force characteristics of the final sample. People who expressed interest in participating based on the initial mailing outreach were scheduled for interviews. Thematic saturation was reached before additional recruitment contact could be made to participants who had not initially expressed interest, i.e. no cold calling was required.
11. Method of approach	How were participants approached? e.g. face-to-face, telephone, mail, email	Eligible patients were identified via medical record databases with approval from primary care physicians. An initial mailing including a letter from the project PI, a study information sheet, and copies of the HIPPA Authorization and Participant Bill of Rights, was sent to patients' homes. Many eligible patients contacted study staff via email, phone, and mail. Verbal consent was obtained at the beginning of the scheduled qualitative interview time for all participants, which took place virtually at a time convenient for the participant.
12. Sample size	How many participants were in the study?	We sought to recruit ~30 participants to achieve thematic saturation with respect to patient experiences with wildfire smoke and with representation across multiple zip codes covered by Kaiser Permanente Northern California.

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No. Item	Guide questions	Description
13. Non-participation	How many people refused to participate or dropped out? Reasons?	Of the 2,112 patients who received the initial mailing, 62 contacted us via phone, email or mail to decline participation. 2 patients scheduled but no showed for an interview, but were not consented because consent would have been collected at the beginning of the interview. No enrolled participants ended their interview early or dropped out of the study.
Setting		
14. Setting of data collection	Where was the data collected? e.g. home, clinic, workplace	Interviews were conducted over Microsoft Teams via computer or phone call.
15. Presence of non-participants	Was anyone else present besides the participants and researchers?	Non-participants (family/friends) could have been present in the background for the interview at the discretion of the participant but this was not monitored. No recording had the voices of non-participants. Sound quality was not degraded by background noise.
16. Description of sample	What are the important characteristics of the sample? e.g. demographic data, date	Refer to Table 1 for participant demographics and to the Results section for important data which emerged.
Data collection		
17. Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested?	An interview guide was developed by the PI and study staff (L.C.M., C.M.L., K.A.D.) with consultation and review by the qualitative research expert (A.A.), to ensure completeness, appropriateness of the wording of the questions and ability to gather the intended information. The full guide is provided in the Supplement as well. Pilot testing on patients was not performed.
18. Repeat interviews	Were repeat interviews carried out? If yes, how many?	Participation ended once the initial interview was complete with no additional follow-up.

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No. Item	Guide questions	Description
19. Audio/visual recording	Did the research use audio or visual recording to collect the data?	Interviews were audio recorded, transcribed and reviewed for interview quality. The transcripts were deidentified.
20. Field notes	Were field notes made during and/or after the interview or focus group?	The PI (L.C.M) took field notes as she listened to the recordings after they occurred.
21. Duration	What was the duration of the interviews or focus group?	The recorded interviews (excluding consent process to maximize privacy) ranged from 21-45 minutes (median time 31 minutes).
22. Data saturation	Was data saturation discussed?	Thematic saturation was achieved after 31 completed interviews.
23. Transcripts returned	Were transcripts returned to participants for comment and/or correction?	Participation in the study ended once the interview was complete. Transcripts or themes were not sent to patients.
Domain 3: Analysis and findings		
Data analysis		
24. Number of data coders	How many data coders coded the data?	Two of the team members (C.M.L., J.Y.) conducted initial coding on several interviews to check for consistency. PI L.C.M. was involved in the coding process as referee and to finalize the code book. A.A. provided expert consultation to ensure the results would be meaningful. Final coding for all interviews was completed by one team member (J.Y.).
25. Description of the coding tree	Did authors provide a description of the coding tree?	Including the PI and consulting qualitative research expert, four study team members (L.C.M., A.A., C.M.L., J.Y.) developed and revised the codebook prior to and during initial coding. The codebook was developed based on three primary domains: the patient's understanding and relationship with smoke, facilitators/barriers for protecting health from smoke, and awareness and understanding of prescribed burns.

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No. Item	Guide questions	Description
26. Derivation of themes	Were themes identified in advance or derived from the data?	We performed traditional thematic analysis through the iterative process of analyzing patterns in qualitative data (Miles and Huberman, Qualitative Data Analysis, 1994). We took both inductive and deductive approaches. Initially, an inductive approach was utilized where themes emerging from participants' responses were collected into a codebook.
27. Software	What software, if applicable, was used to manage the data?	Dedoose software, version 10.0.25 was used for analysis.
28. Participant checking	Did participants provide feedback on the findings?	Participant did not provide feedback on the findings.
Reporting		
29. Quotations presented	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g. participant number	Illustrative quotations were presented in the Results. Quotations were not attributed to specific participants.
30. Data and findings consistent	Was there consistency between the data presented and the findings?	There was consistency between the interview data and the findings presented.
31. Clarity of major themes	Were major themes clearly presented in the findings?	Three major themes from our analysis are reported in the Results section.
32. Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes?	We discussed diverse cases, including experiences from those with firefighting experience and those renting (not owning) their homes.

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Supplementary Material S2. Participant Interview Guide/Script

Moderator's Introduction:

Thanks so much for taking the time to talk with me today. My name is NAME and I am a JOB TITLE at the Division of Research for Kaiser Permanente Northern California. As we discussed during the recruitment call, we're interested in understanding how people with COPD experience smoke from wildfires. As you know, in the past few years, we've had many large wildfires that last for weeks or, even months, and affect nearly everyone's breathing. You were invited to partake in this interview because you have chronic obstructive pulmonary disease (COPD). People with COPD can have difficulty breathing when there is smoke in the air, so we want to hear from you about your experiences. We're going to be using the information you and others share with me to come up with ways to support people with COPD both before and during future wildfire events.

I want to go over a few things. We understand that for anyone who's had a loss of property or loved ones in a wildfire, this may be upsetting to talk about so we are sensitive to this. If there are questions that you don't want to answer, you don't have to answer. The information you share will not be part of your medical record, and everything you say will be kept confidential among my colleagues on the research team. There are no right or wrong answers, and we encourage you to speak freely in whatever way is comfortable for you. Your name won't be used in any publication or other materials that come out of our discussion. What you say will make a difference in our being able to support people with COPD through future wildfire seasons.

IF SCHEDULED ON A DIFFERENT DATE THAN THE VERBAL CONSENT, CONFIRM CONSENT: In an interview like this, the most important thing is your experience and opinions. Because this is a research project, I do need you to confirm that we have your consent to do this interview?

PAUSE

Great, I'm very interested in exactly what you say, so I'm going to record the interview so I can review the interview later. I want to make certain that you're ok with this?

PAUSE

Do you have any questions before we start?

PAUSE

Okay, let's get started then. These interviews usually take about 45 minutes, sometimes less, sometimes more, depending on how much you want to tell me. If you

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need to take a break to focus on your breathing at any time, just let me know. I'm going to turn on the recorder. To protect your privacy, please do not mention names or identifying information while we record.

Interview:

Relationship with and understanding of smoke

Q. People have a range of experiences with smoke over the course of their lives, such as growing up with wood-burning heaters in the house, roasting marshmallows over a campfire, living through large wildfires. Can you tell me about how smoke may have affected you in these different types of situations, from the time you were young until recently?

- Have you ever needed to evacuate your home due to wildfires or had a house burn down?

Q. In the past five years or so, about how often have you been smelling smoke where you live?

- How aware of wildfire smoke are you on a week to week basis?

Q. What is your understanding of how smoke affects your health?

- Can you walk me through how smoke gets into the body and affects your organs?
- To what extent do you think your body is affected by smoke one time versus long term?

Q. Often people have symptoms, like cough or shortness of breath, when they breathe in smoke. Can you describe what symptoms, if any, you've noticed when there is smoke in the air from a wildfire?

- Can you tell me about times when you developed symptoms that you thought were related to smoke but you couldn't actually smell it?
- Do you ever need to use rescue inhalers because of wildfire smoke?
- If you use supplemental oxygen, do you need to turn up the number of liters of supplemental oxygen to help your breathing?
- During wildfires, have you ever needed to go to see the doctor to help you with your breathing?

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Protecting your health from smoke

Q. People get information about wildfires in various ways, such as news on the TV, the internet, radio in the car, friends and neighbors. How do you tend to hear that there is a wildfire near you that could bring smoke to your neighborhood?

- Can you tell me about any alert systems you're aware of or subscribe to?
- Can you tell me about how familiar you are (if at all) with low cost sensors, like PurpleAir?

Q. If you wanted to know current and/or future air quality, what resources would you use?

- How often would you check?
- What would be the most useful time interval to know when poor air quality will occur?

Q. Can you tell me about anything your doctor might have told you to do when there is smoke in the air from wildfires?

- What is the most helpful thing someone has said to do to prevent breathing in smoke from wildfire?

Q. When people are living close to wildfires, there are things they can do to protect their breathing. Can you tell me about anything you might have done during recent fires to protect your health during wildfire events?

Q: Here are some potential ways people avoid smoke exposure:

  - wearing masks outdoors
  - putting your vehicle on air recirculation setting
  - staying indoors as much as possible
  - using portable air cleaner devices
  - ensure the tight sealing of windows and doors in your home
  - ensure the filter on the house heating/cooling unit is clean

Can you tell me about why you don't or wouldn't do any of these? Examples might be the cost, they don't seem worth the hassle, I would need help with that or I didn't know those things could help.

- Is there anything that would make you use any of these more?

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Q. Let's say you were planning to go for a walk outside, to get the mail or take out the trash, but there is smoke in the air from a nearby wildfire. What would make you decide NOT to go outside for the walk. For example, some people might decide not to go out based on how dark (grey, orange) the sky is, how strong the smell of smoke is, how strong the warning messages are from government agencies (EPA, CDC). Do any of these resonate with you?

Q. We're in the process of designing a program to help people in the community be able to stay healthy during periods of poor air quality due to wildfire smoke. What are your thoughts on how Kaiser Permanente could help you when the air is filled with wildfire smoke?

- Here are examples of what we could do to help. Do any resonate with you?
    - Send you an informational pamphlet at the beginning of wildfire season (spring) that contains a checklist to prepare for wildfire season, such as a reminder to change the air filter in your heating/air conditioning system
    - Send you real-time electronic messages warning of poor air quality in the next 1-2 days
    - Deliver equipment directly to your home during periods of poor air quality (masks, air cleaner)
    - Deliver prescriptions directly to your home in the mail during periods of poor air quality
- If you said that real-time electronic messages would be helpful, how would you want to be contacted so the messages are the most helpful to you, such as secure message, text, telephone call with voicemail?
- Who do you trust most to get information about how you might be affected by smoke in the air?

Prescribed burns

Q. Outside of large wildfire events, there can be local, planned fire-related events, like burning brush or piles of dead branches, that can happen in communities. This is called a "prescribed burn." As you might already know, they're intentional fires with the goal of managing the land or burning fuels to prevent large wildfires. Can you tell me anything you might know about planned burns – for example....

- Have you ever had a planned burn in your neighborhood?
- (if yes) Do you/did you receive notifications about planned burns?

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- To what extent have you ever developed respiratory symptoms as a result of a planned burn?
- Do you think the idea of a planned burn makes sense to prevent large wildfires even if they have a cost of producing a small amount of smoke?

Conclusion:

Thank you so much for taking the time to talk with me today. I have learned so much from what you've shared with me about your thoughts and experiences. Is there anything we haven't talked about that would give me a better understanding of how wildfires affect your breathing? I really appreciate your perspective.

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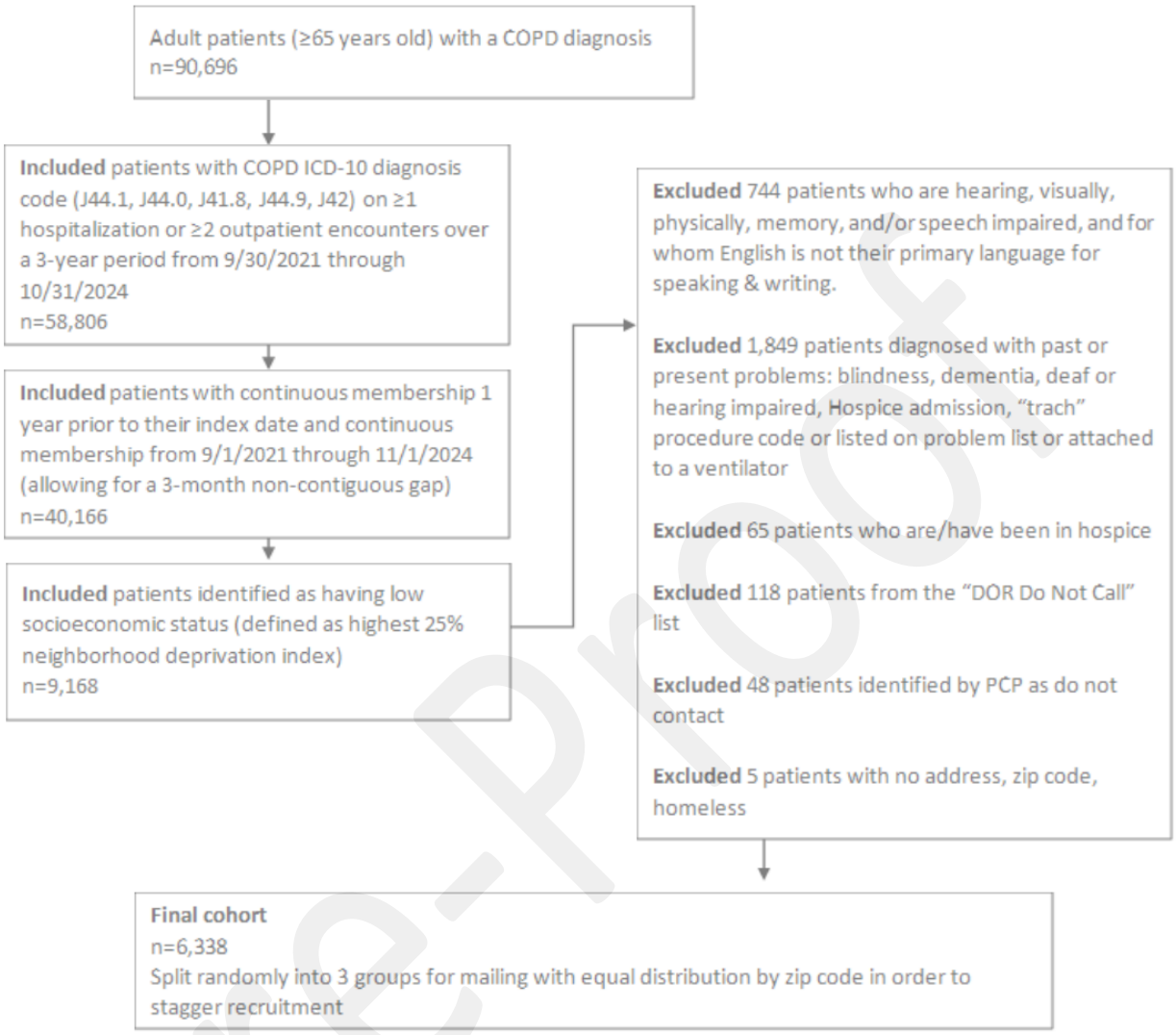
Supplementary Material S3: Flow Diagram of Eligibility List



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Supplementary Material S4. Qualitative Analysis Code Book

1) Relationship with and understanding of smoke
   a) Experience with smoke (including smoking cigarettes/cigars) (open-ended)
   b) Awareness of smoke (time interval) (number of times over last 5 years and weekly frequency)
   c) Evacuation due to wildfires in past? (Yes/No)
      i) Yes
      ii) No
   d) How smoke impacts health (example: enters nose/mouth, impact breathing)
   e) Impact of one-time exposure vs cumulative exposure
      i) One-time exposure
      ii) Long-term, repeated exposures
   f) Direct impacts from smoke (symptoms, use rescue inhaler/more O2, see doctor) (if ppt doesn't endorse symptoms as related to smoke, don't count symptoms)
      i) Eye irritation
      ii) Cough
      iii) Shortness of breath
      iv) Sore throat
      v) Dizziness / Weakness
      vi) Chest pain / tightness
      vii) Sinus issues
      viii)None
   g) Actions due to smoke
      i) Increased necessity for inhaler use
      ii) Increased necessity for oxygen supply
      iii) Increased symptoms to the point of needing a doctor visit
2) Protecting your health from smoke
   a) Sources of information related to smoke
   b) Time interval for knowing air quality forecast
   c) Physician counseling related to smoke (Yes/No)
      i) Yes
      ii) No
   d) Most helpful thing someone has said related to smoke
   e) Mitigation tactic: Staying Indoors
      i) In use / Does this
      ii) Open to adoption (not currently in use/ does not do)
      iii) Not likely to adopt (not currently in use/ does not do)
      iv) Reason to use/not use
   f) Mitigation tactic: Wearing Masks When Outdoors

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i) In use / Does this
ii) Open to adoption (not currently in use/ does not do)
iii) Not likely to adopt (not currently in use/ does not do)
iv) Reason to use/not use

g) Mitigation tactic: Using Vehicle Air Recirculation Setting
i) In use / Does this
ii) Open to adoption (not currently in use/ does not do)
iii) Not likely to adopt (not currently in use/ does not do)
iv) Reason to use/not use

h) Mitigation tactic: Checking Home's Ventilation System Filters
i) In use / Does this
ii) Open to adoption (not currently in use/ does not do)
iii) Not likely to adopt (not currently in use/ does not do)
iv) Reason to use/not use

i) Mitigation tactic: Sealing Windows/Doors
i) In use / Does this
ii) Open to adoption (not currently in use/ does not do)
iii) Not likely to adopt (not currently in use/ does not do)
iv) Reason to use/not use

j) Mitigation tactic: Utilizing Portable Air Cleaners
i) In use / Does this
ii) Open to adoption (not currently in use/ does not do)
iii) Not likely to adopt (not currently in use/ does not do)
iv) Reason to use/not use

k) Top reason for not going outside

l) Receptiveness to potential KP interventions
i) Potential Intervention: Informational pamphlet at beginning of wildfire season
ii) Potential Intervention: Kaiser electronic messages (emails)
iii) Potential Intervention: Phone calls/text messages
(1) Preferred method for contact
(2) Trusted source of the message
iv) Potential Intervention: Delivering equipment (Masks, air filters, prescriptions)
v) Potential Intervention: Other

3) Prescribed burns

a) Prescribed Burn Exposure/Experience?
i) Yes
(1) Familiarity with / notifications
(2) Symptoms due to prescribed burn
ii) No

b) Acceptance of prescribed burns

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