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## Concise Communication

# Air exchanges, climate change, and severe acute respiratory coronavirus virus 2 (SARS-CoV-2): Results from a survey of the Society of Healthcare Epidemiology of America Research Network (SRN)

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## Abstract

In this cross-sectional survey, we assessed knowledge, attitudes and behaviors regarding operating room air-change rates, climate change, and coronavirus disease 2019 (COVID-19) pandemic implications. Climate change and healthcare pollution were considered problematic. Respondents checked air exchange rates for COVID-19 and ~25% increased them. Respondents had difficulty completing questions concerning hospital heating, ventilation and air conditioning (HVAC) systems.

**Keywords** air exchanges; climate change; COVID-19; HVAC; operating rooms

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Climate change is the greatest public health threat of the 21st century.<sup>1</sup> Healthcare is a major polluting industry, responsible for 8.5% of US greenhouse gas emissions.<sup>2</sup> Mitigating healthcare pollution is integral to first doing no harm. Heating, ventilation, and air conditioning (HVAC) accounts for 70%–97% of operating room (OR) energy usage.<sup>3,4</sup> Healthcare HVAC systems could be safely manipulated to reduce energy use and environmental impact.<sup>5</sup>

The American Society for Health Care Engineering (ASHE) hospital HVAC recommendations for ORs (unchanged during our survey) include (1) minimum efficiency reporting value (MERV) filter ratings of  $\geq 14$ , (2) positive pressure ORs, and (3) minimum of 20 air changes per hour (4 outdoor air changes per hour minimum).<sup>6</sup> In a 2019 review of ASHE HVAC recommendations, outdoor air changes per hour and minimum total OR air changes per hour were rated as needing ‘further investigation’ due to little supporting clinical evidence, and other hospital area parameters had little or poor-quality evidence.<sup>7</sup> Current standards are based on staff comfort, odor control, fire prevention, and

infection prevention; however, little evidence correlates air-change rates and outcomes including surgical site infections (SSIs).<sup>7</sup>

We surveyed current OR air-change rate practices, including any set-back transitions (ie, decreasing air changes during off hours), as well as attitudes about climate change, and OR change rates in light of the COVID-19 pandemic.

## Methods

The Washington University School of Medicine Institutional Review Board approved the survey, and it was pilot tested with 5 experts. The 36-item anonymous survey was distributed to the American Hospital Association (AHA) by nondedicated e-mail and the Society for Healthcare Epidemiology of America Research Network (SRN) by dedicated e-mail from October 2020 to February 2021. Within the SRN, 67 US institutions (1 recipient per hospital) received 4 notifications. Data were collected using Qualtrics software (Seattle, WA). Descriptive statistical analyses were performed using SPSS version 27 software (IBM, Armonk, NY).

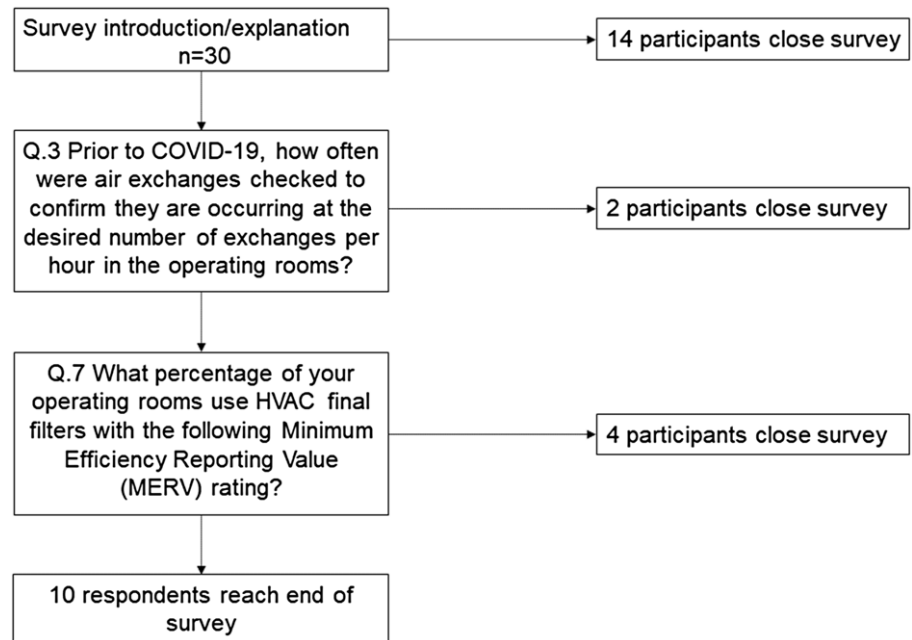
## Results

The AHA survey recipients had response rates <1% and were excluded from analysis. Of 67 SRN participants, 30 (45%) opened the survey. Of these 30 participants, 10 (15%) completed the survey, and 20 (30%) partially completed it (Fig. 1).

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**Fig. 1.** Flow diagram of participants' survey completion.

Among respondents, 7 (70%) were male, 8 (80%) were white, 7 (70%) were aged >50 years, 8 (80%) were hospital epidemiologists, and 2 (20%) were infection preventionists. Six respondents were from academic hospitals, 3 were from a community-based hospital, and 1 was from a Veterans Affairs hospital. The hospitals of 80% of respondents had >250 beds.

### Climate

Overall, 10 (100%) respondents agreed or strongly agreed that “pollution caused by the healthcare industry is important to minimize” and “I am concerned about climate change” (Table 1). Regarding the statement “There is no limit to the amount of resources we should use to prevent even one patient from developing a hospital-acquired infection,” 1 (10%) agreed or strongly agreed, 3 (30%) were neutral, and 6 (60%) disagreed or strongly disagreed.

### Air change rates

Of 16 respondents, 14 (88%) did not decrease OR air-exchange rates during off hours before the pandemic. Before the COVID-19 pandemic, among these 14 respondents, 86% checked air exchanges more frequently than annually.

The percentages of air change from outdoor air varied. Overall, 1 respondent reported 100% external (outside) air changes (the most energy-intensive strategy); 2 respondents reported 35%–99% external air changes; and 3 respondents reporting each of the following: <20% external air, 20%–24% external air, and 25%–29% external air. Of 10 respondents, 9 (90%) used HEPA final filters in some ORs, and final filters were changed at least every 2 years in the institutions of all respondents (100%). In response to COVID-19, 6 (60%) of 10 did not increase MERV filter rating because it was not desired, 1 (10%) did not because filters were unavailable, 2 (20%) did not because it exceeded HVAC design, and 1 (10%) increased MERV filter rating (this respondent had <100% OR HEPA filter use at baseline).

Regarding opinions on national standards for OR air change rates, 6 (60%) of 10 felt that they should remain unchanged, 2 (20%) had no opinion or did not know, and 2 (20%) thought that they should increase. None felt that rates should decrease. This question did not specify whether respondents should include consideration of the coronavirus disease 2019 (COVID-19) pandemic.

### COVID-19

Among 14 respondents, 11 (79%) reviewed code-required air-change rates because of COVID-19; 8 (73%) made no changes, 18% increased air-change rates, and 9% decreased air-change rates. Among these 14 respondents, 10 did not increase the fraction of outside air supplied to ORs. Of these 10, 2 (20%) were retrofitted OR HVACs to accommodate COVID-19 patients (ie, turned ORs from positive to negative pressure). Table 1 lists further details.

### Discussion

Despite little evidence to support their use from an infection control perspective,<sup>7</sup> US healthcare institutions use high energy-intensive air-change rates, even exceeding recommended minimums. Reductions in air changes in acute care has the potential for large energy, financial, and carbon savings.<sup>5,8</sup> Our survey's respondents indicated that climate change, pollution, and the healthcare industry's impact thereon were considered important. Despite absence of evidence of benefit, the extent to which HVAC energy resources should be used to prevent infections varied. For example, ~90% of respondents did not engage in set-back practices in ORs during off hours.

Approximately 80% of respondents reported that they checked OR air-change rates and filters because of COVID-19, some altered air changes or other presumptive infection prevention measures. There was little agreement about whether or how air-change rate standards should be changed. Such uncertainty perhaps resulted from the paucity of evidence for relationships between air-change rates and infections,<sup>7</sup> guideline unfamiliarity, or both.

**Table 1.** Statement and Responses Regarding Climate Change, Energy, and Infections

| What percentage of your operating rooms use the following minimum air exchanges per hour during surgeries? (N = 16), mean %  |  |   |  |                                     |       |
|--|--|---|--|-------------------------------------|-------|
| ≤12  | 13–16  | 17–20                                     | >20  |                                     |       |
| air exchanges per hour   | air exchanges per hour   | air exchanges per hour                    | air exchanges per hour   |                                     |       |
| 6.8  | 23.4   | 32.2                                      | 37.5   |                                     |       |
| Do you decrease the air exchange rates in your operating rooms during off hours (eg, nights/weekends)? (N = 16), no. (%)   |  |   |  |                                     |       |
| Yes  |  |   | No   |                                     |       |
| 2 (12.5)   |  |   | 14 (87.5)  |                                     |       |
| What is the air exchange rate decreased to during off hours (air exchanges/hour)? (N = 2)  |  |   |  |                                     |       |
| 13–16 air exchanges per hour   |  |   | >20 air exchanges per hour   |                                     |       |
| 1  |  |   | 1  |                                     |       |
| What percentage of operating rooms have their air exchange rate decreased during off hours? (N = 2), mean %  |  |   |  |                                     |       |
| Decreased to ≤12 air exchanges per hour  | Decreased to 13–16 air exchanges per hour                          | Decreased to 17–20 air exchanges per hour | Decreased to >20 air exchanges per hour  | No change in air exchanges per hour |       |
| 0  | 15   | 0   | 0  | 85                                  |       |
| Prior to COVID-19, how often were air exchanges checked to confirm they are occurring at the desired number of exchanges per hour in the operating rooms? (N = 14), no. (%)                                    |  |   |  |                                     |       |
| 0–3 mo   | 3–6 mo   | 6–12 mo                                   | 1–2 y  | >2 y                                | Never |
| 5 (36)   | 2 (14)   | 5 (36)                                    | 2 (14)   | 0                                   | 0     |
| Did your facility review operating room code-required air change rates as part of your COVID-19 response? (N = 14), no. (%)  |  |   |  |                                     |       |
| Yes  |  |   | No   |                                     |       |
| 11 (79)  |  |   | 3 (21)   |                                     |       |
| If you answered yes to the previous question (ie, operating room air-change rates were reviewed because of COVID-19), as a result of the review, what did you do with your air-change rates? (N = 11), no. (%) |  |   |  |                                     |       |
| Increased  |  | No change                                 |  | Decreased                           |       |
| 2 (18)   |  | 8 (73)                                    |  | 1 (9)                               |       |
| For a typical operating room at your institution, what percentage of your operating room air exchanges are from outdoor air (rather than from internal return)? (N = 12), no. (%)                              |  |   |  |                                     |       |
| <20%   | 20%–24%  | 25%–29%                                   | 30%–35%  | 35%–99%                             | 100%  |
| 3 (25)   | 3 (25)   | 3 (25)                                    | 0  | 2 (17)                              | 1 (8) |
| Did your facility increase the fraction of outside air supplied to operating rooms during COVID-19? N = 14 (%)   |  |   |  |                                     |       |
| Yes  |  |   | No   |                                     |       |
| 4 (29)   |  |   | 10 (71)  |                                     |       |
| If you answered yes to the previous question (ie, the fraction of outside air supplied to operating rooms was increased during COVID-19), how was the fraction changed? (N = 1)                                |  |   |  |                                     |       |
| Updated to current code minimums   | Increased as high as the system could go while maintaining comfort |   | Changed to 100% outside air to potentially reduce the risk of COVID-19 cross contamination |                                     |       |
| 1  |  |   |  |                                     |       |
| What percentage of your operating rooms use HVAC final filters with the following Minimum Efficiency Reporting Value (MERV) rating? (N = 10), mean %   |  |   |  |                                     |       |
| <13  | 13   | 14  | 15–16  | 17–20 (HEPA filters)                |       |
| 0  | 2  | 0   | 19   | 79                                  |       |
| Prior to COVID-19, how often were operating room HVAC final filters changed (on average with typical use)? (N = 9), no. (%)  |  |   |  |                                     |       |
| 0–3 mo   | 3–6 mo   | 6–12 mo                                   | 1–2 y  | >2 y                                |       |
| 0  | 4 (44)   | 3 (33)                                    | 2 (22)   | 0                                   |       |
| Did your facility increase the filtration MERV rating of your air handling unit filters during COVID-19? (N = 10), no. (%)   |  |   |  |                                     |       |
| Yes  | No, not desired  | No filters available                      | No, exceeds HVAC design limitations  |                                     |       |

(Continued)

Table 1. (Continued)

|  |                         |                              |                   |  |                                     |        |
|--|-------------------------|------------------------------|-------------------|--|-------------------------------------|--------|
| 1 (10)   | 6 (60)                  | 1 (10)                       | 2 (20)            |  |                                     |        |
| <b>Did your facility retrofit the operating room HVAC system to accommodate COVID-19 patients? (N = 10), no. (%)</b>   |                         |                              |                   |  |                                     |        |
| Yes  |                         | No                           |                   |  |                                     |        |
| 2 (20)   | 8 (80)                  |                              |                   |  |                                     |        |
| <b>Which of the following (before COVID-19), if any, devices do you use in your operating room to try to prevent surgical site infections? (Check all that apply.) (N = 10), no. (%)</b>   |                         |                              |                   |  |                                     |        |
| UV light robot   | Standalone HEPA filters | In duct UV or photocatalytic | Ceiling-based UV  | Other (please list)                                      | None                                |        |
| 5 (50)   | 0                       | 2 (20)                       | 1 (10)            | 0  | 4 (40)                              |        |
| <b>Which of the following, if any, extra HVAC precautions did you take in your operating rooms during COVID-19? (N = 10), no. (%)</b>  |                         |                              |                   |  |                                     |        |
| UV light robot   | Standalone HEPA filters | In duct UV or photocatalytic | Ceiling-based UV  | Anteroom retrofit and/or negative pressure peration room | Other (please list)                 | None   |
| 3 (30)   | 1 (10)                  | 1 (10)                       | 0                 | 4 (40)   | 1 (10) – “1 negative pressure room) | 3 (30) |
| <b>In your opinion, in general, national standards for air exchange rates in operating rooms should _____. Please use free text to state why you made your choice. (N = 10), no. (%)</b>   |                         |                              |                   |  |                                     |        |
| Increase   | Decrease                | Stay the same                |                   | I don't know   |                                     |        |
| 2 (20)   | 0                       | 6 (60)                       |                   | 2 (20)   |                                     |        |
| <b>Does your hospital have an environmental sustainability or green initiative/committee/officer? (N = 10), no. (%)</b>  |                         |                              |                   |  |                                     |        |
| Yes  |                         | No                           |                   | I don't know   |                                     |        |
| 5 (50)   | 5 (50)                  |                              | 0                 |  |                                     |        |
| <b>How much do you agree/disagree with the following statement: “Pollution caused by the healthcare industry is important to minimize.” (N = 9), no. (%)</b>   |                         |                              |                   |  |                                     |        |
| Strongly agree   | Agree                   | Neutral                      | Disagree          | Strongly Disagree  |                                     |        |
| 4 (44)   | 5 (55)                  | 0                            | 0                 | 0  |                                     |        |
| <b>How much do you agree/disagree with the following statement: “I am concerned about climate change.” (N = 9), no. (%)</b>  |                         |                              |                   |  |                                     |        |
| Strongly agree   | Agree                   | Neutral                      | Disagree          | Strongly Disagree  |                                     |        |
| 4 (44)   | 5 (55)                  | 0                            | 0                 | 0  |                                     |        |
| <b>How much do you agree/disagree with the following statement: “Energy conservation is NOT important.” (N = 10), no. (%)</b>  |                         |                              |                   |  |                                     |        |
| Strongly agree   | Agree                   | Neutral                      | Disagree          | Strongly Disagree  |                                     |        |
| 0  | 1 (10)                  | 0                            | 6 (60)            | 3 (30)   |                                     |        |
| <b>How much do you agree/disagree with the following statement: “There is no limit to the amount of resources we should use to prevent even one patient from developing a hospital-acquired infection.” (N = 10), no. (%)</b>  |                         |                              |                   |  |                                     |        |
| Strongly agree   | Agree                   | Neutral                      | Disagree          | Strongly Disagree  |                                     |        |
| 1 (10)   | 0                       | 3 (30)                       | 5 (50)            | 1 (10)   |                                     |        |
| <b>What was your standardized infection ratio for 2018 (publically reported data, <a href="https://www.medicare.gov/hospitalcompare/search.html?#">https://www.medicare.gov/hospitalcompare/search.html?#</a>) for colon surgical site infections? (N = 10), mean (SD)</b> |                         |                              |                   |  |                                     |        |
| 1.05 (±0.7)  |                         |                              |                   |  |                                     |        |
| <b>If you are at a Veterans' Affairs Hospital, what was your colon surgical site infection rate for 2018? (N = 1)</b>  |                         |                              |                   |  |                                     |        |
| 1.00   |                         |                              |                   |  |                                     |        |
| <b>My primary institution is (Check all that apply to your primary institution.) (N = 10), no. (%)</b>   |                         |                              |                   |  |                                     |        |
| Community-based  | Academic                | Ambulatory                   | Veterans' Affairs | Critical access hospital                                 | Other                               |        |
| 3 (30)   | 6 (60)                  | 0                            | 1 (10)            | 0  | 0                                   |        |
| <b>There are _____ acute-care beds at my primary institution. (N = 10), no. (%)</b>  |                         |                              |                   |  |                                     |        |

(Continued)

Table 1. (Continued)

| 0–25   | 26–250                  | 261–500                          | 501–750               | 751–1,000                           | >1,000 | 0/<br>ambulatory<br>center |
|--|-------------------------|----------------------------------|-----------------------|-------------------------------------|--------|----------------------------|
| 0  | 2 (20)                  | 4 (40)                           | 2 (20)                | 1 (10)                              | 1 (10) | 0                          |
| In which state is your primary institution? (required to understand weather, climate, and energy mixes only) |                         |                                  |                       |                                     |        |                            |
| CT, DC, GA, IN, MD, NH, PA, TX, WA   |                         |                                  |                       |                                     |        |                            |
| My primary job description is _____. (N = 10), no. (%)   |                         |                                  |                       |                                     |        |                            |
| Infection preventionist  | Hospital epidemiologist | Engineer                         | Facilities management | Other                               |        |                            |
| 2 (20)   | 8 (80)                  | 0                                | 0                     | 0                                   |        |                            |
| I am ____ years old. (N = 10), no. (%)   |                         |                                  |                       |                                     |        |                            |
| 18–29  | 30–39                   | 40–49                            | 50–59                 | 60–69                               | >70    |                            |
| 0  | 2 (20)                  | 1 (10)                           | 5 (50)                | 1 (10)                              | 1 (10) |                            |
| I have been in practice for ____ years (not including training). (N = 10), no. (%)                           |                         |                                  |                       |                                     |        |                            |
| <5   | 6–10                    | 11–15                            | 16–20                 | 21–25                               | 26–30  | >30                        |
| 0  | 1 (10)                  | 2 (20)                           | 2 (20)                | 2 (20)                              | 2 (20) | 1 (10)                     |
| What is your sex? (N = 10), no. (%)  |                         |                                  |                       |                                     |        |                            |
| Male   | Female                  | Other                            | Prefer not to answer  |                                     |        |                            |
| 7 (70)   | 2 (20)                  | 0                                | 1 (10)                |                                     |        |                            |
| What is your race? (N = 10), no. (%)   |                         |                                  |                       |                                     |        |                            |
| White  | African American        | American Indian or Alaska Native | Asian                 | Native Hawaiian or Pacific Islander | Other  | Prefer not to answer       |
| 8 (80)   | 0                       | 0                                | 0                     | 0                                   | 0      | 2 (20)                     |

### HVAC standards and set-back opportunity

Evidentiary gaps exist on optimal air-change settings for healthcare facilities.<sup>7</sup> The current standard (ASHRAE 170) recommends a minimum OR rate of 20 air changes per hour including  $\geq 4$  outside air changes. Minimum air-change values are required only while the room is occupied. Shutting off OR ventilation systems off hours results in energy or cost savings without exceeding particle-count thresholds.<sup>9</sup> Yet, our survey response (85% respondents) suggests that facility operators do not decrease air changes during off hours. This finding may reflect unfamiliarity with the lack of evidence on the relationship between OR ventilation rates and SSI prevention.

Future studies should ascertain relationships between air-change rates and SSIs, using the extant natural experiment of institution-to-institution variability to elucidate opportunities for energy, pollution, and cost savings.

### Pandemic response

ASHRAE created an epidemic task force (<https://www.ashrae.org/technical-resources/resources>) to collect emerging evidence and guidance. Recommendations ultimately followed current ventilation standards (ASHRAE 62.1 and 170) and encouraged additional air filtration when possible.

Numerous institutions tried reducing risks associated with operating on COVID-19 patients. Overall, 79% of respondents reviewed air-change rates because of COVID-19, and 73% of these made no changes. This finding implies that prescribed standard flow rates had already been achieved and/or that the system could not be updated. Moreover, 60% responded that mandated

air-change rates should remain unchanged. Outside air fractions varied, and 71% made no changes.

Our survey had several limitations. We had low response rates (30% partial response rate, 15% complete), though this rate is similar to that of other surveys (response rates,  $\sim 20\%$ ).<sup>10</sup> Response rates raise these questions: What gaps in air-change rate understanding remain unfilled, and how can this improve?

In conclusion, high air-change rates in ORs are financially costly and have commensurate, possibly unjustified environmental impacts. With uncertain HVAC efficacy on one hand and certain high financial and environmental impacts on the other, we require evidence indicating whether current OR air-change rates influence SSIs. Even with current standards, opportunity exists for off-hour setbacks to reduce energy expenses, to prevent pollution, and to protect public health.

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**Conflicts of interest.** R.A.M. reports that he is a member of the Board of Directors of the International Ultraviolet Association. All other authors report no conflicts of interest relevant to this article.

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