Holistic Approach to Enhance Airborne Infection Control Practices in Health Care Facilities Involved in the Management of Tuberculosis in a Metropolitan City in India – An Implementation Research

Abstract

Background: Airborne infection control (AIC) is a less focused aspect of tuberculosis (TB) prevention. We describe AIC practices in primary health care centres, awareness and practices of AIC among health care providers (HCPs) and TB patients. We implemented a package of interventions to improve awareness and practices among them and assessed its impact. **Methodology:** The study used a quasi-experimental study design. A semi-structured checklist was used for health facility assessment and a self-administered questionnaire of HCPs. Pre- and postintervention assessments were made in urban primary health centers (UPHCs), HCPs, and patients. Interventions included sharing facility-specific recommendations, AIC plans and guidelines, HCP training, and patient education. Statistical difference between the two time periods was assessed using the Chi-square test. **Results:** A total of 23 and 25 UPHCs were included for pre- and postintervention assessments. All 25 centers participated in interventions. Open areas were >20% of ground area in all facilities. No AIC committee was present in any of the facilities at both pre- and postintervention. Of all HCPs, 7% (23/337) versus 65% (202/310) had undergone AIC training. Good awareness improved from 24% (81/337) to 71% (220/310) after intervention ($P < 0.001$). Appropriate cough hygiene was known to 20% (51/262) versus 58% (152/263) patients at two assessments ($P < 0.001$). **Conclusion:** Comprehensive intervention, including supportive supervision of health centers, training of HCPs, and patient education, can improve AIC practices.

Keywords: *Airborne infection control, health-care facilities, health-care providers, implementation, tuberculosis*

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Introduction

An estimated 2.4 million cases of tuberculosis (TB), an airborne infection, were notified in 2019 from India.[1] Simple measures such as opening windows and doors provide natural ventilation and play a major role in airborne infection control (AIC).[2] Exposure to an untreated infectious TB source for 24 hours in poorly ventilated hospitals is adequate to infect more than one-third of susceptible persons.[2] There is increased exposure and risk to health-care providers (HCPs) in high-burden low-resource settings.[3] The prevalence of TB infection ranged from 33% to 79%, with an average of 54% among HCPs in low- and middle-income countries.[4] TB infection among HCPs can be reduced with administrative controls.[5] Evaluation of AIC practices in TB facilities in South Africa showed that the awareness of staff was low and it varied in different facilities.[6]

The Indian National Guidelines for AIC in health-care settings to provide guidance for reducing the risk of TB and other airborne pathogen transmission was published in 2010.[7] The hierarchy of controls to reduce TB transmission risk are administrative controls which include identifying respiratory symptomatic, fast-tracking their management, and avoiding unnecessary admission; environmental controls, which include optimal ventilation, appropriate seating arrangements, and germicidal irradiation; and personal protective equipment (PPE).[7] A multicentric study in India that evaluated AIC practice implementation noted a substantial improvement in the implementation of AIC policies

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and practices after improving awareness and offering facility-specific recommendations.[8]

We did a study in Chennai, the most populous city in Tamil Nadu, South India, to understand AIC practices in Urban Primary Health Centres (UPHC) settings, among patients HCPs and patients. Identification of strengths and gaps in AIC implementation would help to strengthen the program towards the goal of TB elimination. The objectives of the study were to describe AIC practices in UPHCs providing TB care services, awareness, and practices of AIC among HCPs and TB patients. The study also aimed to do facility, HCPs, and patient-targeted interventions and assess the impact of those interventions by comparing selected indicators for awareness and practices of AIC at those three levels at two points, pre- and postintervention.

Methodology

The study design was an interventional, quasi-experimental design (pre–postdesign) done in UPHCs providing only outpatient care, including TB care services in two zones with high TB case load of Chennai Corporation. We recruited HCPs and patients from the same UPHCs selected for AIC assessments. The study was approved by the Institutional Ethics Committee of the Indian Council of Medical Research-National Institute for Research in TB (ICMR-NIRT). Necessary approval from the regulatory body was also obtained.

Health facility assessment

We used a pilot-tested semi-structured observation checklist based on the National AIC guidelines.[7] We collected information regarding the availability of the AIC committee, infection control plan, measures for administrative, environmental control, and PPE. We used Digital Thermo Anemometer KM909 to measure air velocity from openings, Bosch digital unit to measure the volume of rooms, and mobile phone cameras to take pictures for documentation.

Administrative control

We observed administrative control indicators, including screening, segregation, and fast tracking of respiratory symptomatic, patient education, display of educational materials, and appropriate biomedical waste (BMW) management in outpatient department (OPD) and laboratories.

Environmental control

We observed environmental control indicators including facilities for natural ventilation, presence of openings greater than 20% of floor area, presence, placement and usage of mechanical and mixed mode ventilation etc. We measured air changes per hour (ACH) in areas of patient and HCP interaction. As per the guidelines,[7] ideal ACH should be >6 for OPD, waiting areas, and >12 for high-risk settings. Optimal seating arrangements for ideal airflow direction between HCPs and patients were also documented.[8]

Personal protective equipment

We assessed the availability of PPE such as surgical masks and N95 respirators and their appropriate usage.

Cross-sectional survey of health-care providers

We prepared a line list of HCPs in the selected UPHCs and made at least two attempts to include them. Eligible HCPs who had given written informed consent were consecutively enrolled. We collected information regarding education, work experience, AIC training, awareness, and practices using a self-administered questionnaire under supervision. Regarding awareness, a set of ten questions covering various aspects of AIC was included in the questionnaire. Awareness was graded as good (>75%) for 8 or more correct answers, average (50-75%) for 5 to 8 answers and poor (<50%) if they had correctly answered for less than five questions.

Scenario-based questions were given to HCPs to assess their awareness. (a) Cross-ventilated rooms with open doors and windows reduce the risk of airborne disease transmission, (b) fast tracking of respiratory symptomatic/smear-positive TB patients in OPD, (c) segregation of respiratory symptomatic in well-lit ventilated space, (d) cough etiquette – closing of mouth and nose while coughing, (e) well-lit and ventilated outdoor space for sputum collection for testing, (f) burning sputum in a paper or tissue or collect sputum in a vessel with ash/lime, and (g) HCP to wear N95 during aerosol generation procedures such as nebulization.

Assessment at two time points

A trained team, including clinicians, medical social workers, field investigators, and civil engineers, conducted health center assessment, HCP, and patient surveys at both the time points. Preintervention assessments were started in December 2019 and completed in July 2020 (health centers), September 2020 (HCPs), and mid-November 2020 (patients). COVID-19 pandemic had an impact on patient and HCP recruitment and took a longer duration than anticipated to complete. Postintervention assessments were conducted between March and September 2021. We made at least two visits to the centers to include the same HCPs in both the assessments. We could not include patients interviewed in preintervention assessment in the postintervention assessment if their treatment completion occurred before the second assessment.

Interventions

The interventions included strengthening already existing strategies as per National AIC guidelines but not in practice such as facilitating the availability of facility AIC implementation plan and National AIC guidelines, capacity building of HCPs and patient education along with newer interventions such as facility based AIC assessment with respect to three key pillars (administrative control, environmental control and PPE) and recommendations for improvement. Two separate check lists covering various areas of AIC for HCP's and patient's education were used. The details of various interventions are given in Table 1.

Postintervention assessment

Health facility assessments, HCP, and patient surveys were done 3 months after the completion of interventions using the same tools used at baseline.

Data management

Data were entered and managed using REDCap electronic data capture tools hosted at ICMR-NIRT. Data were analyzed using SPSS version 25 (Statistical Package for the Social Sciences Inc., Chicago, IL, USA). Values were expressed as frequency, percentages, median, and interquartile range (IQR). Statistical difference between proportions of independently observed factors during pre- and postintervention was determined using Chi-square and Fisher's exact test. Facility-based indicators were also compared using McNemar's test. The knowledge score of HCPs collected during both the assessments was compared using Student's *t*-test. The tests were two-sided, with a Type I error set at a = 0.05.

Results

Health-care facility

A total of 23 and 25 UPHCs providing TB services were assessed at two time points. Baseline assessments were not done in two centers functioning in a temporary structure with a plan for shifting later. As preintervention assessments and interventions were done for HCPs and patients in those two centers, they were included in postintervention facility assessment. The AIC committee was not present in any of the centers at pre- and postintervention. AIC plan and National AIC guidelines were not available in any of the centers (23) during preintervention whereas it was available in all centers (25) during postintervention as it was given to them by the team.

An average number of rooms and windows in each of the facilities were 14 and 19, respectively. On an average, six rooms in a center had cross ventilation. Almost all centers had rooms with open areas, more than 20% of ground area. Out of 75 assessed rooms, where ACH was measured, two had ACH <6/h and the rest had >12/h. Disinfection of sputum smears and containers with 5% phenol before disposal was observed in all centers in both the assessments. The results of pre- and postintervention assessments in health centers are summarized in Table 2.

Table 1: Interventions to improve the airborne infection control practice implementation in urban primary health-care facilities providing tuberculosis care services

Interventions	Activities
Facility-wise recommendations	Based on preintervention assessment
	Detailed facility-wise report including strengths, weaknesses, and recommendations for improvement shared with the facility in-charge and program manager
	Follow-up visits for interaction with HCPs for implementation of appropriate practices
Facility-wise AIC implementation plan	Development and sharing of AIC plan template with the facility-in-charge
	Meeting with the facility-in-charge and provided guidance for completion of AIC plan
Distribution of guidelines to the health-care facilities	National AIC guidelines 2010 and Infection Control guidelines 2021
Capacity building for HCPs	Two-day training program
	First day - National AIC guidelines
	Second day - Sharing of strengths and gaps observed in preintervention assessment and training in areas of gaps in AIC implementation
	Educational videos using mock scenarios were also used
Capacity building of HCPs (individual level)	Checklist for HCP education with focus on patient education, facility-level practices, best practices in PPE usage, laboratory practices, hand hygiene, etc.
IEC of patients	IEC materials in local language (Tamil)
	Eight different posters displayed in the health centers covering general AIC measures, cough etiquette, safe disposal of sputum, laboratory infection control, and airborne diseases prevention
	Pamphlets distributed to patients with the focus on respiratory hygiene, mask usage and safe disposal, sputum disposal, and proper ventilation
Patient education (individual and group counseling)	Checklist was used which included mode of TB transmission, respiratory hygiene, treatment compliance, importance of ventilation, and hand hygiene

AIC: Airborne infection control, TB: Tuberculosis, IEC: Information, Education and Communication, HCPs: Health-care providers

Health-care providers

A line list of 349 HCPs for the preintervention and 369 for the postintervention assessment was created. Among them, 337 and 310 HCPs participated in pre- and postintervention assessments, respectively. Of all, four HCPs were not willing to participate during both the assessments. The study team was not able to meet the other nonrecruited HCPs even after two attempts due to various reasons such as deputation for other duties, including COVID, on long leave, etc. The awareness of AIC measures and its practices in centers and laboratories from the HCP survey are given in Table 3. The median age was 39 (19–60) and 40 (20–65) years during pre- and postintervention assessments, respectively. Among the HCPs, 89% (n = 300) and 88% (n = 272) were females at pre- and postintervention assessments, respectively. Of them, 47% (n = 158) and 46% (n = 143) were employed permanently and the rest were either working on a

temporary basis or for daily wages; the staff cadre included medical officers 8% (n = 28) versus 7% (n = 23), health nurses 40% (n = 134) versus 37% (n = 113) during pre- and post intervention assessments, respectively. The rest of the staff cadre included senior treatment supervisors, health visitors, auxiliary nursing midwives, laboratory technicians, pharmacists, and multipurpose health workers.

The pre- and postintervention comparison of awareness regarding appropriate AIC practices is given in Figure 1. The awareness of administrative control practices such as fast tracking and segregation of respiratory symptomatic, appropriate cough etiquette, environmental control practices such as appropriate ventilation, place of sputum collection, and self-protection during high-risk procedures show significant improvement after intervention (P < 0.001). The median (IQR) score for the awareness questions in the preintervention assessment was 6 (2–10) and in the postintervention assessment was 8 (4–10).

Patients

A total of 262 and 263 patients were interviewed whose median ages were 46 (18–75) and 47.5 (18–81) in pre- and postintervention assessments, respectively. During the preintervention assessment, 78% (n = 205) were males, 15% (n = 39) were illiterates, 85% (n = 223) had formal education (middle school and above), and 78% (n = 203) were married. Among 262 participants, 36% (n = 95) were unemployed, 47% (n = 123) were working for daily wages, 11% (n = 29) had temporary employment, and 6% (n = 15) had permanent employment. The AIC practices of patients during both the assessments are given

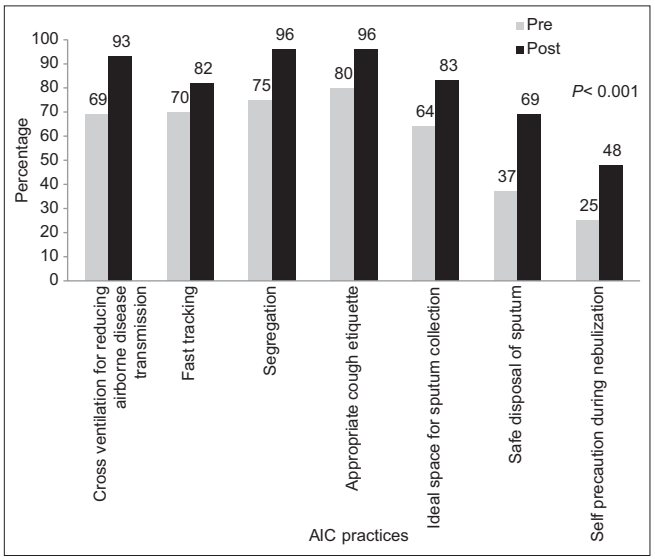

Figure 1: Pre- and postintervention awareness of health-care providers about appropriate AIC practices in a metropolitan city, India. AIC: Airborne infection control

Table 2: Pre- and postintervention airborne infection control practices in urban health-care facilities providing tuberculosis services in a metropolitan city

Characteristics	Preintervention (n=23), n (%)	Postintervention (n=25), n (%)	P
Administrative controls			
Screening of respiratory symptomatic on arrival at the clinic*	2 (9)	22 (88)	<0.001
Fast tracking of respiratory symptomatics	0	22 (88)	<0.001
Separate waiting area for respiratory symptomatics	0	18 (72)	<0.001
Education of patients regarding respiratory hygiene	2 (9)	24 (96)	<0.001
Education of patients regarding cough etiquette	2 (9)	24 (96)	<0.001
Education of patients regarding safe disposal of sputum	1 (4)	22 (88)	<0.001
Display of IEC materials regarding cough etiquette	17 (74)	25 (100)	0.006
Display of IEC materials regarding safe disposal of sputum	4 (17)	24 (96)	<0.001
Availability of masks in the facility for patients	12 (52)	16 (64)	0.406
Distribution of masks to respiratory symptomatics	2 (9)	14 (56)	<0.001
Education of patients regarding safe disposal of masks	1 (4)	13 (52)	<0.001
Disposal of biomedical waste as per guidelines	20 (87)	25 (100)	0.062
Place of collection of sputum in a well-lit ventilated outside area	20 (87)	22 (88)	0.913
Environmental control			
Seating arrangements as per guidelines	7 (30)	23 (92)	<0.001
Functional ceiling fan in all rooms	20 (87)	22 (88)	0.913
Work benches in the laboratory cleaned with 70% alcohol	9 (39)	22 (88)	<0.001
PPE			
Funds available for N95 masks to staff	13 (62)	17 (63)	0.247
Facilities with N95 masks	8 (38)	20 (80)	<0.001
Staff using N95 mask while providing care to symptomatics	1 (0.4)	19 (70)	<0.001

*Screening of the respiratory symptomatic could not be observed in 3 centers and 2 centers in the pre- and postintervention assessments, respectively. Similarly separate waiting area for the respiratory symptomatic could not be observed in 2 centers during postintervention due to COVID-19-related changes in health-care facilities. PPE: Personal protective equipment, IEC: Information, Education and Communication

in Table 4. That TB can be cured was known to 248 (95%) versus 256 (98.5) in pre- and postintervention assessments, respectively (P = 0.03). The comparison of patient's awareness during both the assessments is given in Figure 2.

Discussion

Almost all centers had a good infrastructure for adequate ventilation; however, optimal utilization by keeping the doors and windows open could be improved. None of the facilities had an AIC committee pre- and postintervention. All facilities were equipped with an AIC plan and AIC guidelines postintervention. In our setting, 65% of HCPs mentioned having attended at least one training in AIC guidelines during postintervention assessment compared to 7% of them at preintervention assessment.

Table 3: Pre- and postintervention awareness and practice regarding airborne infection control among health-care providers in the urban health-care facilities providing tuberculosis care services in a metropolitan city

Characteristics	Pre (*n*=337), *n* (%)	Post (*n*=310), *n* (%)	*P*
Underwent training in AIC practices	23 (7)	202 (65)	<0.001
Staff awareness of AIC* (%)			
Poor (<50)	60 (18)	7 (2)	<0.001
Average (50-75%)	196 (58)	83 (27)	<0.001
Good (>75%)	81 (24)	220 (71)	<0.001
AIC practices reported in the health facilities			
Respiratory symptomatic screening on arrival in their center	299 (89)	296 (96)	0.002
Place where respiratory symptomatic wait in the center			
Along with others	177 (53)	24 (8)	<0.001
Well-ventilated separate waiting room	136 (40)	286 (92)	<0.001
Others	15 (5)	0	<0.001
Don't know	9 (3)	0	0.004
Availability of masks for patients in their center	233 (69)	254 (82)	<0.001
AIC training material/guidelines available in the center	5 (2)	199 (64)	<0.001
AIC plan available in the center	9 (3)	201 (65)	<0.001
Availability and display of AIC IEC materials in the center	274 (81)	294 (95)	<0.001
AIC practices reported by the HCPs in the health facilities			
Cough hygiene advice to a respiratory symptomatic	312 (93)	305 (98)	<0.001
Ever worn N95 masks while taking care of high-risk patients	122 (36)	269 (87)	<0.001
Underwent TB screening in the center	59 (18)	76 (25)	0.028
Awareness of laboratory technicians	**Pre (*n*=39), *n* (%)**	**Post (*n*=38), *n* (%)**	***P***
70% alcohol used to clean the workstations	14 (36)	21 (55)	<0.001
5% phenol is used for disinfecting sputum slide before discarding	33 (85)	34 (90)	0.066
5% phenol is used as disinfectant for handling spills	33 (85)	34 (90)	0.066

*There were 10 questions in the health care worker questionnaire for awareness. For these 10 questions, if the score is > 80% then we considered awareness as good, between 50 and 75% as average and less than 50% as poor. AIC: Airborne infection control, TB: Tuberculosis, IEC: Information, Education and Communication, HCPs: Health-care providers

Table 4: Pre- and postintervention airborne infection control practices among tuberculosis patients accessing services in urban health-care facilities in a metropolitan city

Characteristics	Pre (*n*=262), *n* (%)	Post (*n*=263), *n* (%)	*P*
Standing in line to see the doctor	104 (40)	23 (9)	<0.001
Standing in line for laboratory tests	45 (17)	5 (2)	<0.001
Educated about cough hygiene	228 (87)	258 (98)	<0.001
Educated about the safe disposal of sputum	200 (76)	258 (98)	<0.001
Received IEC materials regarding respiratory hygiene	2 (1)	66 (25)	<0.001
Received mask from the center	46 (18)	8 (3)	<0.001
Place of sputum collection			
Inside the toilet	106 (41)	44 (17)	<0.001
In the laboratory	0	0	NA
In the waiting area	2 (1)	3 (1)	0.656
In a well-ventilated area with sunlight	144 (55)	212 (81)	<0.001
Others	10 (4)	4 (2)	0.103

IEC: Information, Education, and Communication

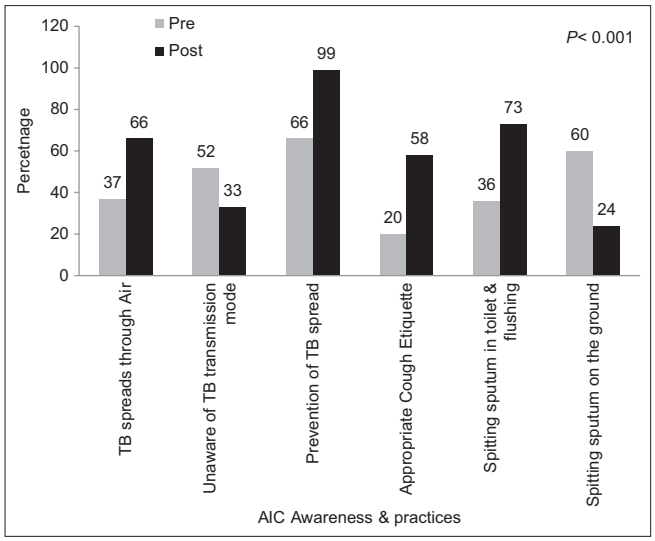

Figure 2: Pre- and postintervention awareness and practices of AIC practices among TB patients accessing services in the urban health-care facilities in a metropolitan city. Appropriate cough etiquette: Closing of mouth and nose while coughing. Prevention of TB spread: Adherence to TB treatment, cough hygiene and staying in well-ventilated rooms AIC: Airborne infection control, TB: Tuberculosis

Administrative control features such as screening, fast tracking, segregation, and patient education improved significantly after intervention. Improvement in the segregation of respiratory symptomatic was noted during observation as well as reported by HCPs. Infrastructural challenges limited segregation in few centers. In a study among different health-care settings in Kerala, practices such as fast tracking (18%), segregation of respiratory symptomatic (24%), and education (10%) were observed. Sputum disposal, as per BMW management (86%), was observed in the same facilities.[9] Appropriate BMW management practices were higher in our setting. Seating arrangements in areas of HCP and patient interaction, appropriate usage of N95 masks improved significantly. Improvement in mask availability and distribution to respiratory symptomatic was noted and done in around half of the facilities. However, the proportion of TB patients who received a mask from the center was comparatively lower during postintervention assessment. This could probably be because of wider mask usage by the community at large during the pandemic and patients could have already worn masks.

Awareness was high for indicators such as wearing N95 masks, appropriate sputum disposal, low for fast-tracking TB patients, and minimum ACH in controlled settings among HCPs from a tertiary center in Kerala.[10] Improvement in the knowledge scores of HCPs was noted in our setting. Almost three-fourth of HCPs had good awareness in the postintervention survey compared to one-fourth in preintervention assessment. The awareness of laboratory technicians regarding disinfection of workspace, smear slides, and spills was above 80% at both the time points.

Almost one-fourth of the patients received an AIC educational material during the second assessment compared to <1% during preintervention assessment. Knowledge regarding the airborne transmission of TB improved significantly during postintervention assessment among patients. A study among TB patients in Ambala City, North India, showed that around 54% followed unsafe practices for sputum disposal, similar to our results during preintervention assessment.[11] Sputum disposal by spitting on the ground decreased and safe sputum disposal practices improved during the second patient survey.

Nosocomial spread of TB in high and low TB incidence settings as well as high HIV prevalence settings has been widely reported.[12-14] Improvement in natural ventilation brings about three-fourth reduction in TB transmission risk.[15] Lack of training, poor dissemination of guidelines, lack of commitment, infrastructural factors, and higher patient load were barriers to AIC practice implementation.[16] Other factors, such as HCP's attitude, vacant posts, and nonfunctional infection control committees, also contribute to poor implementation.[17] The commitment of the facility-in-charges favored the implementation of AIC practices in our observation. Turnover of facility-in-charges also impacted the implementation. Supportive supervision with facility-specific recommendations, ensuring execution of the AIC plan by designated staff, will be fruitful. Regular training and ongoing education of HCPs in AIC guidelines are vital. Ongoing behavior change communication for the community at large and patients will be necessary to improve respiratory hygiene practices. Awareness and implementation of AIC guidelines and factors influencing them will vary at different health-care levels. Further research is needed to identify the strengths and gaps of AIC implementation at different levels and to understand factors associated with implementation challenges to plan effective interventions.

Limitation

This study done in one city might not be generalizable to all geographic regions. However, understanding the strengths and weaknesses of AIC implementation will help to customize and strengthen it in other regions. The COVID-19 pandemic could have impacted the study as behavior change due to increased awareness for few AIC practices, such as mask usage, could not be ruled out.

Conclusion

A comprehensive and customized approach of assessing and strengthening the AIC practice implementation at health-care centers, HCP, and patient levels is effective and is of great importance for health system preparedness to face any current and emerging airborne health challenges.

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Conflicts of interest

There are no conflicts of interest.

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