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Donning of personal protective equipment under direct supervision- A quality improvement study in COVID-ICUs of a tertiary care facility, South India

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ABSTRACT

Background: Personal protective equipment has a major role in reducing the transmission of infections to healthcare workers despite the fact that improper doffing techniques can pose a threat of acquiring nosocomial infections. Compliance to donning or doffing is an all or none phenomenon where lack of adherence to sequence or technique can result is transmission of infections. Conducting doffing audit with the help of trained supervisors (dofficers) can significantly improve compliance with doffing guidelines.
Materials and Methods: This quality improvement study, was conducted at a large-scale tertiary care hospital located in South India, for a one-year period in COVID-ICUs. Doffing audit was conducted by trained dofficers in designated doffing areas for proper technique & sequence of doffing and disposal all through the shifts.
Results: 5834 health care professionals were supervised over 8760 hours with a total doffing compliance of 66.6%. Nurses had better overall and individual component doffing compliance. Biomedical waste segregation compliance was also high among nurses (90.4%). Most common breach is with mask removal.
Conclusion: Nosocomial transmission of infections can be controlled with adherence to proper doffing techniques. Auditing and on spot interventions will help improve the compliance to doffing.

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1. Introduction

The COVID-19 pandemic had a profound global impact. The etiological agent, SARS-CoV-2 virus is extremely infectious, and was responsible for outbreaks in various settings, including healthcare facilities. Nosocomial transmission of SARS-CoV-2 virus can occur through respiratory droplets, contact as well as airborne particles, especially in intensive care units (ICUs), which results in spread of infection to several healthcare workers (HCWs), working in close vicinity to the patient in ICU environment.[1]

Infection prevention and control (IPC) measures targeted to interrupt the transmission may help curtail the spread of the virus. Such steps include performing hand hygiene at every indication, following all the hand hygiene steps correctly, physical distancing of 1-meter from the patient, the appropriate use of personal protective equipment (PPE) and enhanced environmental cleaning. However, COVID-19 care locations have their own set of challenges

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and implementing these otherwise reasonably simple interventions often appear to be difficult. Several studies reported the hand hygiene compliance to be very low in COVID-19 care locations, attributed to the continuous wearing of the same gloves and not changing between the patient care activities. Hospital crowding and nature of work which requires close contact with the patient especially in ICUs often makes physical distancing difficult. Similarly, the healthcare workers were often found to commit several errors during the donning and doffing of PPE.[2–4]

Several guidelines have been laid down which provides recommendation on the technique for donning and doffing of PPE.[5–8] Donning helps to put on and use PPE properly to achieve the intended protection and minimize the risk of exposure, whereas doffing means removing PPE in a way that avoids self-contamination. Although doffing poses more risk on the HCWs, donning is also an important element and breach in donning at times can put the HCWs into risk of contracting infection in their work time. The HCWs are often found to commit several errors during the donning of PPE, which can be attributed to lack of knowledge or practice or attitude.[9–11]

Bundled donning audit with the help of a trained observer, can significantly improve compliance with donning guidelines. The trained observer role was first developed in response to viral haemorrhagic fever outbreaks, for monitoring doffing practices.[12] However, to the best of our knowledge, there is no literature available on conducting donning audit under direct supervision for none of the infectious diseases including COVID-19. Therefore, this quality improvement study was designed to monitor the donning practices of personal protective equipment under direct supervision in COVID-19 ICUs.

2. Materials and Methods

2.1. Audit setting

This study was conducted at a tertiary academic healthcare facility located in South India, from May 2021-April 2022 during the COVID-19 pandemic. Hospital infection control and prevention (HICP) unit took the initiative to conduct the donning audit for the HCWs posted in COVID-19 ICUs. Nine COVID-19 ICUs (catering to nearly 50 beds) were included in the study. The supervisors deployed to conduct the study were the infection control nurses (ICNs) and infection control residents (ICRs) posted in HICP unit under the guidance of the infection control officer (ICO).

2.2. Pre-audit training of HCWs

The HCWs such as doctors, nurses, ancillary staff were posted in different shifts across the day (i.e., morning, evening and night shifts), and the schedule of the posting used to be prepared for a period of one-week, i.e. a new set of HCWs were posted in COVID-19 ICUs every week. At the start of every week, the HCWs were given adequate training on donning and doffing techniques and were certified by the HICP unit before being posting in COVID-19 ICUs. Training was provided by the ICO along with ICNs and ICRs of the HICP unit which consisted of a didactic session on the donning and doffing technique, followed by simulation videos on donning and doffing procedure. The donning protocol used for this study has been adapted from the recommendations of Centres for Disease Control and Prevention (CDC) and World health organization (WHO) (Figure 1, Table 1).[5,6] The competency was assessed using a post-test evaluation, on which HCW had to achieve a score of ≥90% in order to get certified for working in the areas requiring transmission-based precautions.

2.3. Audit tool and process

Donning audit was performed using the mobile phone based digital PPE audit App, developed by JIPMER in collaboration with Ibhar Pvt. Ltd. The audit was performed in the PPE donning area situated outside the COVID-19-ICU zone, while the HCW don PPE before their work shift. During the observation, first the basic knowledge of the HCW on donning technique was informally assessed by the supervisor, and then the HCW was objectively observed and audited while he/she was donning the PPE. Only the essential PPE required for droplet precautions—i.e. gloves (inner and outer pair), respiratory protection PPE (3-ply mask or N95 respirator), protective eyewear (goggles or face shield) and body cover (coverall, gown, or plastic apron) were included for analysis. The Fit/seal check performed by HCW for N95 respirator was also monitored.

The common type of errors or breach which might occur while donning PPE were audited and recorded. The errors were either in the sequence of donning and/or in the method of donning of individual PPE. The primary role of the supervisor was to directly observe the PPE donning process; however, they were also actively providing the feedback for any errors noted, which would prevent the HCW to commit the same error in the subsequent days of the same posting cycle. Although the errors in the donning sequence and/or donning method were immediately corrected on site by the supervisors; the audit data were recorded as ‘error in the sequence or method’ as per the initial attempt made by the HCWs.[13]

2.4. Data analysis

Data analysis was performed using IBM SPSS Statistics Version 25. Descriptive data were expressed as mean and standard deviations. To compare mean for repeat measures, Welch’s ANOVA with Games Howell post hoc testing was used. Post hoc testing was limited to items that were found to be statistically significant on ANOVA testing.

3. Result

3.1. Baseline information

During the study period, a total of 3098 healthcare workers (2013 females & 1085 males) were supervised and audited for PPE donning technique by the supervisors, which comprised 816 (26.3%) doctors, 1467 (47.4%) nurses, 623 (20.1%) ancillary staff and 192 (6.2%) visitor HCWs (which included HCWs who occasional visit COVID-19 ICU such as physiotherapists, phlebotomists, X-ray technician etc.). Cumulatively, the supervisors conducted 8760 hours of auditing during the study period. Significantly fewer audits were done during the night shift (2190 hours; 25%) compared to the morning (3504 hours; 40%) and evening shifts (3066 hours; 35%).

3.2. Components supervised

Table 1 depicts the components supervised during donning audit. 91.3% of HCWs were found to have a good knowledgeon method of donning PPE (doctors 92.9% vs nurses 96.4%), whereas the knowledge on sequence of donning PPE was found to be adequate in 93.8% of HCWs (doctors 96.1% vs nurses 97.4%). The hand hygiene compliance of HCWs before donning was found to be 43.5% (doctors 37.1% vs nurses 60.9%). Overall donning compliance for correct sequence and correct method were found to be 87.3% and 84.2% respectively. 6.1% of males were found to have gross beard (doctors 7.5% vs nurses 3.4%) as in Table 2.

The components of PPE donned by HCWs has been depicted in Table 3. About 89.1% of HCWs were noted to don all the four essential PPEs—i.e. gloves, respiratory protection, protective eyewear, and body cover (doctors 85.2% vs nurses 96.9%). 96.1% of HCWs were found to don gloves (single pair 3.9 % vs two-pairs 94.6%). Respiratory protection was worn by 99.6% of HCWs; 26.4% were found to don only N95 respirator, 16.2% donned only 3ply mask, whereas both N95 respirator and 3ply mask were donned by 57.0% of HCWs. Protective eyewear was worn by 89.9% of HCWs; 57.0% were found to don goggles, 32.4 % donned face shield whereas only 0.5% were found to don both googles and face shield. 99.6% of HCWs were found to don body cover (44.3% coverall vs 53.2% gown). Among the PPE missed during donning, maximum non-compliance was associated with protective eyewear (10.1%), followed by gloves (1.4%).

epicts common breaches that occurred during the donning process. 56.5% of HCWs did not perform hand hygiene before donning. The common errors in the donning sequence were—donning the hood of coverall earlier to goggles (12.5%), followed by N95 worn outer to 3ply mask (11.1%), inner and outer gloves worn together (6.6%), goggles worn earlier to mask (6.3%) and mask worn earlier to gown (5.9%). The common errors in the donning method were—not performing fit/seal check after N95 (15.7%), touching the outer surface of sterile gloves (11.3%) and crisscrossing the straps of 3ply mask and N95 (5.7%). The work shift-wise comparison of breaches that occurred during donning has been analyzed and depicted. Higher errors were noted in the night shift, followed by the evening shift. The week-wise trend analysis revealed that the proportion of errors was found to be more on the first day of the posting and declined significantly from second day onwards.

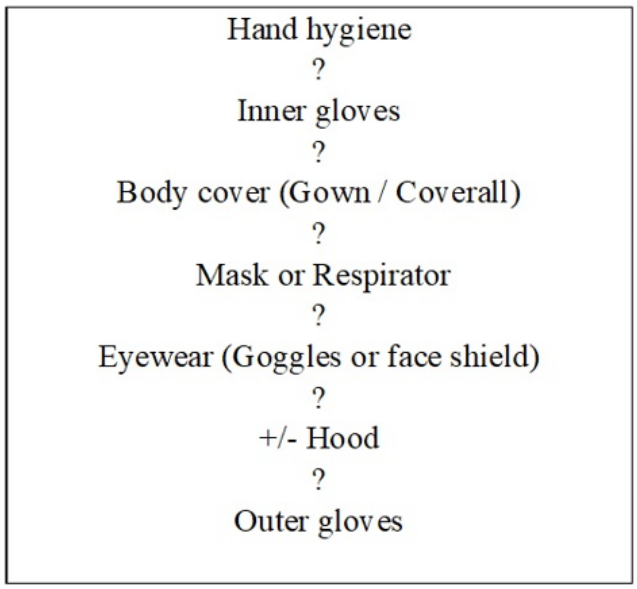

Figure 1: Protocol for donning of PPE (sequence)[5,6]

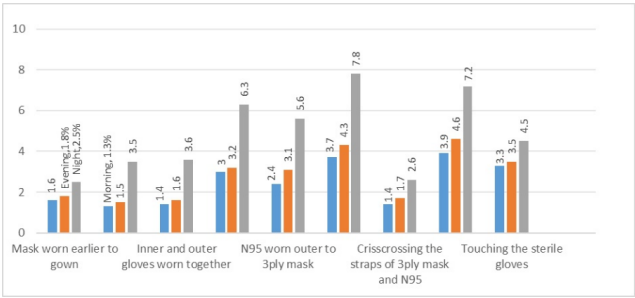

Figure 2: Common breaches during donning among different shifts of duty

4. Discussion

Nosocomial transmission of COVID-19 has resulted into numerous cases of healthcare associated COVID-19 infection among the HCWs worldwide. In COVID-19 ICUs, the transmission risk to HCW is significantly high as these locations cater to sick patients and many of them are on mechanical ventilation posing a higher

Table 1: Method for donning of PPE[5,6]

Gown	• Fully cover torso from neck to knees, arms to end of wrists, and wrap around the back. • Fasten it in the back of neck and wasit
Mask	• Pull the straps tight and pull the mask to below chin and then apply knots. • Press on the nasal bridge part of the mask to seal tightly
Respirator	• Cup respirator under the chin • Pull and locate the lower strap below the ears and upper strap across the crown of the head • Mould the nose clip and perform fit check
Glove	• Donning of the first glove: Wear by touching and pulling only the edge of the cuff. • Donning of the second glove: Avoid touching the forearm skin by pulling external surface of second glove by the finger of gloved hand

Table 2: Components supervised during PPE donning audit among the HCWs of various professional cadres

Components	Doctors N=816	Nurses N=1467	Ancillary staff N=623	Visitors N=192	Total N=3098
Adequate knowledge on method of donning	92.9%	96.4%	83.6%	70.3%	91.3%
Adequate knowledge on sequence of donning	96.1%	97.4%	87.2%	78.6%	93.8%
Performed hand hygiene before donning	37.1 %	60.9%	13.0%	35.9%	43.5%
Performed the correct method of donning	84.1%	90.1%	80.4%	52.6%	84.2%
Followed the correct sequence of donning	88.4%	92.2%	82.0%	63.5%	87.3%
Male HCWs with gross beard	7.5 %	3.4%	6.2%	7.1%	6.1%

N, total number of profession-specific healthcare workers; Ancillary staff include the staff involved in cleaning and housekeeping activities; Visitors includes HCWs who occasionally visited COVID-19 ICU such as physiotherapists, phlebotomists, X-ray technician etc. but not the patient attenders.

Table 3: Components of PPE donned by healthcare workers

Component of PPE	Doctors	Nurses	Group D	Visitors	Total
Donned all PPE	85.2%	96.9%	80.6%	73.4%	89.1 %
Missed at least one PPE	14.8%	3.1%	19.4%	26.6%	10.9%
Gloves	99.6%	98.8 %	99.5%	89.6%	98.5%
One pair	3.3%	1.8%	8.0%	9.4%	3.9%
Two pairs	96.3%	96.9%	91.5%	80.2%	94.6%
Not worn	0.4%	1.2%	0.5%	10.4%	1.4%
Respiratory protection	100%	100%	99.2%	95.8%	99.6%
N95 only	28.1%	28.7%	26.0%	2.6%	26.4%
3ply only	4.4%	3.9%	39.0%	85.9%	16.2%
Both	67.5%	67.4%	34.2%	7.3%	57.0%
Not worn	0.0%	0.0%	0.8%	4.2%	0.4%
Protective eyewear	85.7%	97.3%	82.2%	76.6%	89.9%
Goggles	57.7%	66.6%	36.6%	46.9%	57.0%
Face shield	27.2%	30.5%	44.8%	29.7%	32.4%
Face shield & goggles	0.7%	0.2%	0.8%	0.0%	0.5%
Not worn	14.3%	2.7%	17.8%	23.4%	10.1%
Body cover	100%	100%	99.5%	94.8%	99.6%
Coverall	39.3%	60.7%	12.0%	43.7%	44.3%
Gown	59.9%	38.9%	79.5%	49.5%	53.2%
Plastic apron	0.4%	0.0%	1.9%	0.0%	0.5%
Coverall and gown	0.4%	0.4%	0.0%	1.6%	0.4%
Gown and plastic apron	0.0%	0.0%	6.1%	0.0%	1.2%
Not worn	0.0%	0.0%	0.5%	5.2%	0.4%

Ancillary staff include the staff involved in cleaning and housekeeping activities; Visitors includes HCWs who occasionally visited COVID-19 ICU such as physiotherapists, phlebotomists, X-ray technician etc. but not the patient attenders.

Table 4: Common breaches/errors during donning

Components	Total (N=3098)
Not performed hand hygiene before donning	56.5%
HCWs shown errors in donning sequence	**12.7%**
Mask worn earlier to gown	5.9%
Goggles worn earlier to mask	6.3%
Inner and outer gloves worn together	6.6%
Hood of coverall donned earlier to goggles	12.5%
N95 worn outer to 3ply mask	11.1%
HCWs shown errors in the donning method	**15.8%**
Crisscrossing the straps of 3ply mask and N95	5.7%
Not doing fit check after N95	15.7%
Touching the sterile gloves	11.3%

risk of aerosol, droplet as well as contact transmission. Appropriate donning and doffing of PPE play a vital role in preventing the transmission of the virus in the workplace. The implementation of a trained supervisor to observe PPE donning, combined with an objectively planned donning audit in COVID-19 ICUs is a unique and first-of-its-kind study conducted to identify, evaluate, and communicate potential breaches/errors occurring during the donning process. Through this quality improvement study, we were able to earmark several potential areas where significant improvements can be made possible. [14,15]

Prior to supervising the donning process, the knowledge of the HCWs on donning method and sequence was qualitatively assessed by the supervisors (Table 2). It was noted the HCWs had a reasonably good knowledge (Table 2) on the location specific PPE use, both in terms of PPE method (91.3%) and sequence (93.8%). Nurses were found to have the best knowledge followed by doctors (p value <0.05), whereas the knowledge was found to be slightly poor among the visitor staff (70.3% had a good knowledge on method of PPE donning and 78.6% on sequence of donning) who sporadically come to ICU (which may have resulted due to their improper training and forgetfulness) and among the ancillary staff engaged in housekeeping and cleaning activities (which could be attributed to their poor level of education). When the HCWs were observed while they don the PPE, it was noted that there was a slightly lower rate of compliance to both the method and sequence of donning, compared to their knowledge (p value <0.05). This indicates that knowledge does not always get translated into practice which warrants initiating interventional measures to motivate the HCWs and explain the consequences of erroneous practices in PPE donning. The hand hygiene compliance prior to the PPE donning was found to be exceptionally low in all professional cadres (43.5%, Table 2). Contaminated hands could infect the sterile PPE during the donning process, which could be detrimental. The HCWs were explained the importance of performing pre-donning hand hygiene and this breach was on-site corrected. [16]

The HCWs were monitored for components of PPE they had selected to don (Table 3) and any breaches occurred were noted down (Table 3) and onsite correction with adequate explanation and training was provided. 89.1% of HCWs were noted to don all the four essential PPEs, whereas the remainder of the HCWs (11.9%) did not remember to choose at least one of the essential PPE. A donning audit conducted in a teaching hospital in southern Queensland, Australia revealed an overall donning compliance of 58.61% among doctors, although it varied 40-76% among different specialities. [12] The most common PPE missed in our study population was protective eyewear (10.1%), followed by gloves (1.4%). The above-mentioned Australian study among the doctors found that the donning compliance was lowest for protective eyewear (33%) and mask (36%), followed by gown (55%), and gloves (90%). [12]

Root cause analysis performed had revealed that the noncompliance to don protective eyewear was mainly attributed to two factors— (i) frequent fogging of the goggles and face shields resulting in discomfort at work and difficulty in reading (especially in the nurse and doctor group); (ii) lack of knowledge (especially in the ancillary and visitor group). Protective eyewear is the second most important PPE for COVID-19 (next to respiratory protection) as it serves to prevent droplet transmission through conjunctival mucosa. Absence of protective eyewear could be extremely dangerous even for those HCWs who do not work in close vicinity of the patient. This was explained to the HCWs and onsite corrections were made. They were also informed about certain measures which can limit the fogging of outer surface, such as choosing goggles with anti-fogging coating, non-vented goggles, applying pressure over the nose bridge of the mask to get better seal and fixing it tightly so as to avoid upward flow of air, donning goggles outer to the mask etc. [1]

Similarly, gloves provide protection against contact transmission of COVID-19. The HCWs argued saying that their nature of work does not involve touching the patient and the environment and hand hygiene can be performed on

accidental exposures. However, the supervisors explained to the HCW, that it is practicality impossible to make the hands touch-free while working in the ICU and there could be unanticipated emergencies where the HCW would be forced to touch the patient or his environment. Therefore, wearing of gloves is an important element of donning which cannot be missed. Double gloving was found to be more common across all professional cadres over single pair of gloves (94.6% vs 3.9%). The practice of double gloving gives theoretical advantage of protection against contracting the infection through micropores of the gloves, if at all present. However, it has several undesirable adverse implications such as—(i) poor hand hygiene due to false sense of safety and (ii) discomfort at work due to improper grip of hands. To counteract this adverse implication, hand hygiene over gloved hand was adapted in our COVID-19 ICUs as an interim practice as per the recommendation of CDC.[5,12]

Both respiratory and body protection were missed only in 0.4% of HCWs (Table 3), majority of them were from the visitors group, which was mainly attributed to lack of knowledge and training. Unlike doctors and nurses who were posted weekly and underwent booster training prior to their weekly posting, visitors used to visit the COVID-19 ICU infrequently (not as weekly posting) and were found to have undergone PPE training program long before. This was the reason why the visitor group was found to have higher rates of breaches compared to other groups. Visitors group was trained adequately by the supervisors and errors were onsite corrected. Most HCWs were found to don two respiratory protections (3ply and N95). N95 respirator is more than sufficient to provide adequate protection from respiratory aerosols. However, having a 3ply mask over N95 respirator prevents the contamination of outer surface of N95, thus increases the longevity of N95 use for ≥8 hours. At the same time double masking is a discomfort to the HCW, compromising the oxygenation. The majority of HCWs were found to don gown preferably, as compared to coverall. Gown are more than sufficient to provide adequate protection from contact transmission of droplets of COVID-19. Coverall not only are expensive than gown; but also gives tremendous discomfort to the HCW during work. A minor group (0.4%) of HCWs were found to choose two different body cover (gown and coverall), which is entirely unnecessary and therefore were on-site corrected. Some ancillary staff (6.1%) engaged in cleaning activity in COVID-19-suspect ICU were found to choose two body covers (gown and plastic apron). This was justified with the explanation that, for HCWs with gown, change of the plastic apron in between the COVID-19 suspect patients will obviate the requirement of changing gown each time without compromising their safety.[1,14,15]

Common breaches noted in the sequence of PPE donning include wearing the hood of coverall earlier to goggles (12.5%), followed by donning N95 outer to 3ply mask (11.1%) (Table 4). If the hood of the coverall is donned earlier to the goggles, then strap of googles would remain outer to the hood. Although it will not affect the HCWs during their work, it has an adverse impact during doffing process. While coverall is supposed to be doffed prior to the goggle, the HCW would be forced to doff the goggles earlier to the doffing of coverall, as goggle's strap were over the hood and this would pose a greater risk of contracting the infection through conjunctival mucosa to the HCW. This was explained to the HCWs, and the breach was onsite rectified. Similarly, 11.1% of HCWs were observed to don N95 outer to 3ply mask. This is a serious breach as having a 3-ply mask inside would interfere with the fit/sealing of the N95 respirator over the face and thus it would result in failed fit check and make the N95 totally ineffective to provide aerosol protection. The supervisors gave this explanation to the HCWs, and the breach was corrected immediately.[1,14,15]

The most common breach noted in the method of PPE donning was nonperformance of fit/seal check after N95 (15.7%, Table 4). Fit/seal check is an important test performed after donning the N95 respirator to verify whether the sealing is perfect or not. First, the N95 respirator is pressed at nose bridge and all sides to ensure a tight seal. Secondly, positive seal check is verified by deep exhalation so that the N95 respirator would fill up with air and the HCW would feel any air leakage around the edges. If there is leakage of air, the HCW should adjust the position and/or tension straps. Thirdly, the negative seal check is verified by deep inhalation. The HCWs who missed to perform the fit check were explained the process of fit check and were onsite made to perform fit/seal check.[1,14,15]

The frequency of breaches that occurred during donning were found to vary between the different shifts of duty (Figure 2). Maximum breaches occurred during the night shifts, followed by evening shifts. Lack of strict monitoring mechanism could be the reason for poor donning compliance in the night shift which could have given the HCWs a false sense of relaxation. The HCWs were explained that appropriate donning is a measure of self-protection from contracting infection during work and therefore the responsibility should come from self, even without supervision. It was also noticed that the proportion of errors was found to be more on the first day of the posting and declined significantly from second day onwards over the posting week. This indicates that donning audit with onsite feedback has a tremendous impact on improving the donning compliance. However, as every week roster used to change, the impact of auditing to the same group of HCWs was not carried forward to the subsequent week.[1,9,14,15]

5. Conclusion

In conclusion, we implemented a PPE donning audit program through trained supervisors on HCWs posted in COVID-19 ICUs in conjunction with onsite audit feedback

and correction. Overall, the implementation noted a higher donning compliance of HCWs. Common breaches found were donning googles earlier to hood, not performing fit check, not performing hand hygiene before donning. Feedback was provided to the HCWs about their donning practice and errors found were onsite corrected. Additional research is required to determine if conducting such audits is clinically significant (by follow up of the HCWs over next one week to observe if they have contracted COVID-19) and if the model is logistically and financially sustainable.

6. Ethical Approval

This study was conducted after taking approval from institute ethical committee with ref. no. JIP/IEC/2021/014

7. Conflict of Interest

None.

8. Source of Funding

None.

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