Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Research paper

Personal protective equipment preparedness in intensive care units during the coronavirus disease 2019 pandemic: An Asia-Pacific follow-up survey

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ABSTRACT

Background: Personal-protective equipment (PPE)-preparedness, defined as adherence to guidelines, healthcare worker (HCW) training, procuring PPE stocks and responding appropriately to suspected cases, is crucial to prevent HCW-infections.

Objectives: To perform a follow-up survey to assess changes in PPE-preparedness across six Asia-Pacific countries during the COVID-19 pandemic.

Methods: A prospective follow-up cross-sectional, web-based survey was conducted between 10/08/2020 to 01/09/ 2020, five months after the initial Phase 1 survey. The survey was sent to the same 231 intensivists across the six Asia-Pacific countries (Australia, Hong Kong, India, New Zealand, Philippines, and Singapore) that participated in Phase 1. The main outcome measure was to identify any changes in PPE-preparedness between Phases 1 and 2.

Findings: Phase 2 had responses from 132 ICUs (57%). Compared to Phase 1 respondents reported increased use of PPE-based practices such as powered air-purifying respirator (40.2% vs. 6.1%), N95-masks at all times (86.4% vs. 53.7%) and double-gloving (87.9% vs. 42.9%). The reported awareness of PPE stocks (85.6% vs. 51.9%), mandatory showering policies following PPE-breach (31.1% vs. 6.9%) and safety perception amongst HCWs (60.6% vs. 28.4%) improved significantly during Phase 2. Despite reported statistically similar adoption rate of the buddy system in both phases (42.4% vs. 37.2%), there was a reported reduction in donning/doffing training in Phase 2 (44.3% vs. 60.2%). There were no reported differences HCW training in other areas, such as tracheal intubation, intra-hospital transport and safe waste disposal, between the 2 phases.

Conclusions: Overall reported PPE-preparedness improved between the two survey periods, particularly in PPE use, PPE inventory and HCW perceptions of safety. However, the uptake of HCW training and implementation of low-cost safety measures continued to be low and the awareness of PPE breach management policies were suboptimal. Therefore, the key areas for improvement should focus on regular HCW training, implementing low-cost buddy-system and increasing awareness of PPE-breach management protocols.

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1. Introduction

Intensive care unit (ICU) healthcare workers (HCWs) are at an increased risk of coronavirus disease 2019 (COVID-19) owing to inadequate personal protective equipment (PPE), long-time exposure to infected patients, increased work demand, and more aerosol-generating procedures (AGPs), among other reasons.[1–3] As per our original survey,[4] PPE preparedness, defined as adherence to guidelines, HCW training, procuring PPE stocks, and responding appropriately to suspected cases, is crucial to prevent infections in HCWs.[4] In the early stage of the pandemic (March 25, 2020, and April 6, 2020), a multinational survey was conducted to assess PPE preparedness in ICUs across six countries in the Asia-Pacific region.[4] Wide variations in PPE preparedness were observed both between and within countries, with several ICUs reporting suboptimal PPE training, practice, and stock awareness.[4] There were notable variations in several areas: reported use of negative-pressure rooms, HCW training, PPE stock awareness, reported use of high-flow nasal oxygenation (HFNO) and noninvasive ventilation (NIV), reported use of specialised airway teams, showering policies, and "buddy systems".[4]

Since then, these six countries have experienced differing trends in the epidemiology of COVID-19 cases and the rate of infections in HCWs. At the time of this survey, while India and the Philippines were in the first wave of infections,[5] Australia was experiencing a second wave in some states.[3] Meanwhile, New Zealand (NZ), Singapore, and Hong Kong (HK) had minimal community spread, and the majority of their cases were imported from overseas travellers.[5–7] Similar international surveys on PPE preparedness during the early pandemic identified unprecedented challenges and lack of forward planning among health systems worldwide.[8]

The aim of this follow-up study was to determine if there have been changes in PPE preparedness over time, taking into consideration the changing contexts, such as prone positioning of patients with COVID-19 and ICU policies for PPE breach and PPE reuse. In this article, we report a follow-up survey of the same ICUs across six Asia-Pacific countries.[4]

2. Methods

2.1. Study design

This follow-up survey used the same cross-sectional web-based methodology as our original study.[4] The questionnaire content was based on the EuroNHID project[9] and was validated after several rounds of consensus building process between ICU and infectious disease specialists. As in the original survey, the World Health Organization (WHO) recommendations were chosen as the reference standard.[10] Our initial survey (defined as phase 1 henceforth; Supplementary Material 1) was conducted between March 25, 2020, and April 06, 2020.[4]

2.2. Study setting and population

This survey (defined as phase 2 henceforth) was distributed to qualified consultant intensivists across the same six countries (Australia, NZ, Singapore, HK, Philippines, and India), working in hospitals with a 24/7 emergency/casualty department and an ICU capable of mechanically ventilating patients for at least 24 h. As shown in Supplementary Material 2, we made minor amendments to a few questions to make it in line with the ongoing pandemic, namely, asking questions regarding training for prone positioning of patients with COVID-19 and ICU policies for PPE breach and PPE reuse. After ethical approval by the Nepean Blue Mountains Local Health District Human Research Ethics Committee (approval number: 2020/ETH00705, August 6, 2020), the survey was distributed from August 10, 2020, to September 1, 2020, by email, text messages, and WhatsApp™ to the intensivists from the same 231 ICUs who had responded to the phase 1 survey. Two reminders were sent 1 week apart. As is the initial survey, we only included the first response from each institution. The reason behind this was to avoid the likelihood of multiple intensivists from the same institution responding to the survey by the snowballing method used for distribution.[4] Participation was voluntary, with no incentives offered.

2.3. Definitions

As per the original survey, we defined PPE preparedness as adherence to guidelines, HCW training, procuring PPE stocks, and responding appropriately to suspected cases.[4]

2.4. Data analysis

Data analysis was conducted by two trained authors. Data were reported as proportions, and 95% confidence interval (95% CI) was calculated. No overlap of 95% CI between phase 1 and phase 2 represents significant results. All values and analyses were calculated using STATA 16.0 (StataCorp, Texas, USA).

2.5. Study outcomes

This follow-up survey sought to explore any changes in PPE preparedness between phase 1 and 2, which included PPE practice, HCW training, PPE inventory, and HCWs' perceptions, differences in practices associated with responding appropriately to suspected cases between phase 1 and 2, the locations for management of a sick nonintubated patient with COVID-19, types of noninvasive oxygen therapies, and any differences in family visitation policies. In addition, in phase 2, we explored the policies and protocols surrounding PPE breach management, training for prone positioning, and PPE reuse.

3. Results

A total of 132 intensivists of the 231 ICUs from all the six countries who responded in phase 1 responded in phase 2 (57% response rate). The mean response rate in the phase 2 survey was 63%. Singapore had the highest response rate (6/6, 100%), whereas the Philippines had the lowest (5/16, 31%) (Fig. 1).

3.1. Changes in PPE preparedness

3.1.1. PPE use

There was a statistically significant increase in the reported use of all appropriate PPE required to manage patients with COVID-19 across all countries. There were significant increases in the reported use of powered air-purifying respirators in phase 2 (phase 1: 6.1% [95% CI: 3.4–10.0]; phase 2: 40.2% [95% CI: 31.7–49.0]), in double gloving (phase 1: 42.9% [95% CI: 36.4–49.5]; phase 2: 87.9% [95% CI: 81.1–92.9]), and in the use of N95 masks at all times (phase 1: 53.7% [95% CI: 47.0–60.2]; phase 2: 86.4% [95% CI: 79.3–91.7]). Caps (131/132, 99.2%), visors (126/132, 95.5%), and goggles (126/132, 95.5%) were reportedly used by almost all ICUs in the phase 2 survey (Fig. 2, Supplementary Table 1). There were no reported differences in N95/P2 mask fit-testing (phase 1: 27.3% [95% CI: 21.6–33.5]; phase 2: 30.3% [95% CI: 22.6–38.9]) and the reported use of low-cost observers or "buddy systems" to check donning and doffing procedures (phase 1: 37.2% [95% CI: 31.0–43.8]; phase 2: 42.4% [95% CI: 33.9–51.3]) (Table 1).

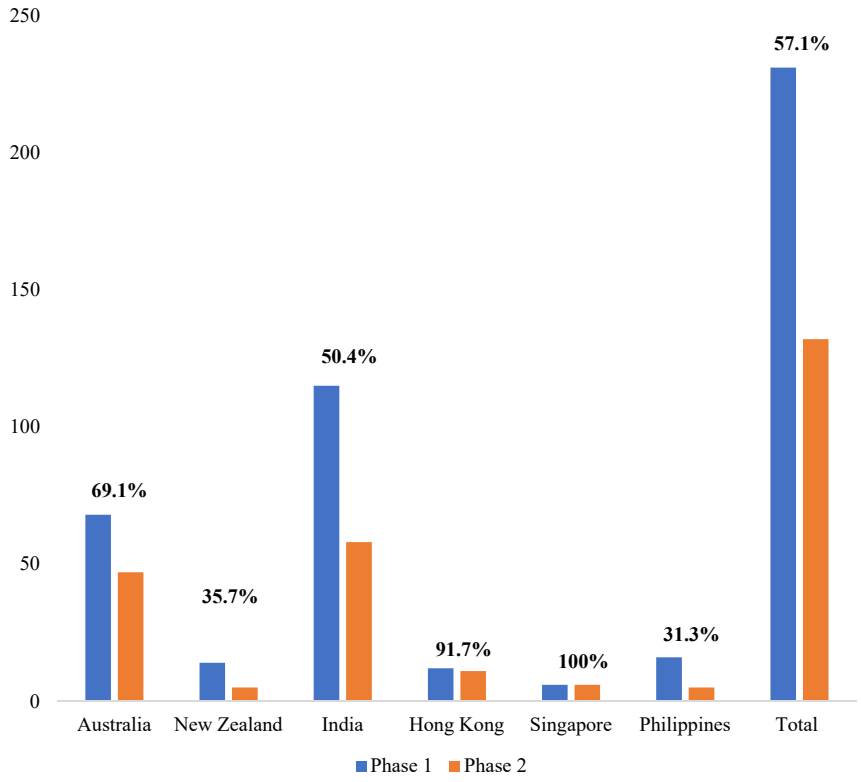

Fig. 1. Overall response rate comparison between phase 1 and phase 2.

3.1.2. HCW training

Overall, there was a reported significant reduction in HCW training for donning and doffing from 60.2% (95% CI: 53.5–66.5) in phase 1 down to 44.3% (95% CI: 35.6–53.2) in phase 2. There was no reported difference in the other HCW training between the 2 phases in all countries. Phase 2 included an additional question regarding training for prone positioning of patients with COVID-19. Twenty percent (26/132) (range: 0% [0/5] in NZ; 33% [2/6] in Singapore) of ICUs had regular training for prone positioning. There was no reported difference in the use of specialised intubation teams between the two phases (65.8% in phase 1 [95% CI: 59.3–71.9] versus 77.9% in phase 2 [95% CI: 69.8–84.6]) (Table 2).

3.1.3. PPE inventory and HCWs' perceptions

Compared with phase 1, there was a significant reported improvement in PPE stock adequacy, with most ICUs reporting they had adequate stocks to manage three patients with COVID-19 for 1 week, from 51.9% in phase 1 (95% CI: 45.3–58.5) to 85.6% in phase 2 (95% CI: 78.4–91.1) (Table 2). In line with this, there was a reported statistically significant increase in the HCWs' perception of increased PPE procurement over the past 2 months in all six countries, from 14.4% in phase 1 (95% CI: 10.1–19.6) to 71.2% in phase 2 (95% CI: 62.7–78.8). The perception of HCW safety had reportedly improved significantly, with the majority of respondents in phase 2 reporting feeling safe (28.4% in phase 1 [95% CI: 22.6–34.7] versus 60.6% in phase 2 [95% CI: 51.7–69.0]). However, variations were observed in HCWs' perceptions regarding PPE practice and likelihood of infections in HCWs. HK, NZ, and the Philippines had a decrease in the number of respondents who felt that PPE practice was optimal in phase 2, whereas India had a statistically significant increase (Table 2).

3.1.4. PPE breach

Policies regarding PPE breach were only explored in phase 2. The most common policy measure for PPE breach reported by respondents was a mandatory reporting to infectious disease experts or designated COVID consultants (38/74, 51%). However, a substantial proportion reported they were either unaware of or that there was no formal policy regarding showering immediately (35/74, 47%), reporting to infectious disease experts or designated COVID consultants/authorities (30/74, 41%), and retraining for donning and doffing (36/74, 49%) after PPE breach (Fig. 3). There was a reported significant increase from phase 1 in the number of ICUs with mandatory showering policies if PPE was breached (phase 1: 6.9% [95% CI: 4.0–11.0]; phase 2: 31.1% [95% CI: 23.3–39.7]) (Supplementary Table 1).

3.1.5. Location to treat patients with COVID-19 receiving noninvasive oxygen therapies

Location for treating patients with COVID-19 remained relatively similar to phase 1. However, there was a statistically significant reduction in the use of only negative-pressure rooms in phase 2 (8.6%; 95% CI: 2.9–19.0) (Supplementary Table 2). In phase 2, fewer respondents stated that noninvasive oxygen therapies were "not an option" for HFNO (26.4% in phase 1 [95% CI: 20.8–32.6] versus 10.6% in phase 2 [95% CI: 5.9–17.2]) and NIV (45.5% in phase 1 [95% CI: 38.9–52.1] versus 21.2% in phase 2 [95% CI: 14.6–29.2]). For all forms of noninvasive oxygen therapies, the use of negative-pressure rooms with overflow increased, with the largest change seen in NIV (9.1% in phase 1 [95% CI: 5.7–13.6) versus 30.3% in phase 2 [95% CI: 22.6–38.9]) (Table 3).

3.1.6. ICU family visitation

In phase 2, family visitation rights were limited to mostly remote communication only across all countries, which

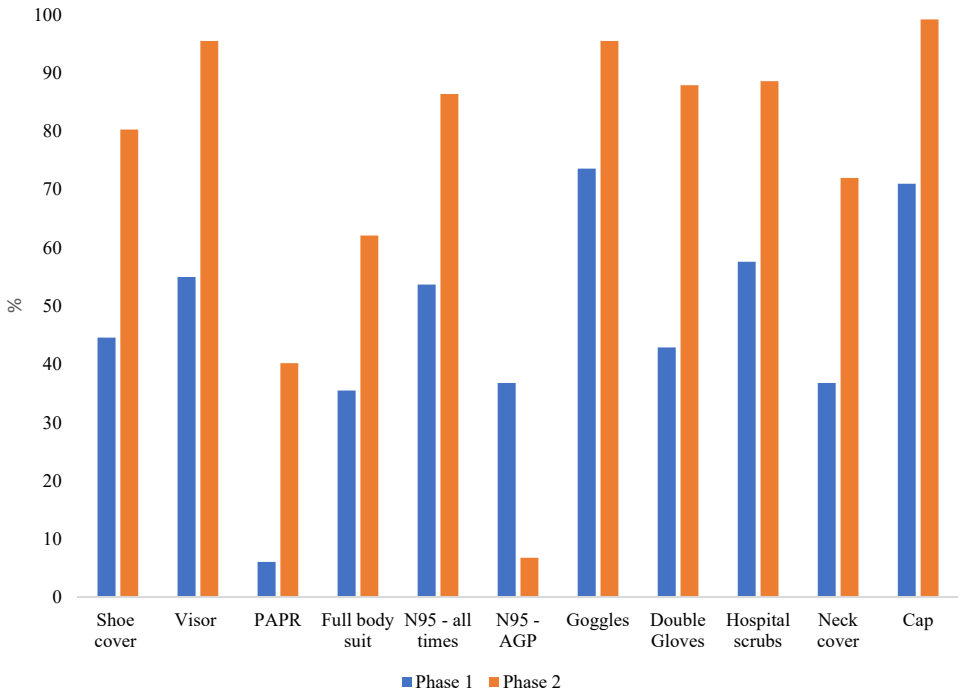

Fig. 2. Individual PPE practices (all countries). AGP = aerosol-generating procedure; PAPR = powered air-purifying respirator; PPE = personal protective equipment.

Table 1
Low-cost measures to ensure PPE safety.

Measures to ensure safety		Australia, n/N (%, 95% CI)	Hong Kong, n/N (%, 95% CI)	India, n/N (%, 95% CI)	New Zealand, n/N (%, 95% CI)	Philippines, n/N (%, 95% CI)	Singapore, n/N (%, 95% CI)	Total, n/N (%, 95% CI)
N95/P2 mask fit-testing	Phase 1	16/68 (23.5, 14.1–35.4)	12/12 (100.0, 73.5–100.0)	13/115 (11.3, 6.2–18.6)	9/14 (64.3, 35.1–87.2)	7/16 (43.8, 19.8–70.1)	6/6 (100.0, 54.1–100.0)	63/231 (27.3, 21.6–33.5)
	Phase 2	10/47 (21.3, 10.7–35.7)	11/11 (100.0, 71.5–100.0)	5/58 (8.6, 2.9–19.0)	5/5 (100.0, 47.8–100.0)	3/5 (60.0, 14.7–94.7)	6/6 (100.0, 54.1–100.0)	40/132 (30.3, 22.6–38.9)
Mandatory use of a "buddy"	Phase 1	35/68 (51.5, 39.0–63.8)	2/12 (16.7, 2.1–48.4)	32/115 (27.8, 19.9–37.0)	9/14 (64.3, 35.1–87.2)	5/16 (31.3, 11.0–58.7)	3/6 (50.0, 11.8–88.2)	86/231 (37.2, 31.0–43.8)
	Phase 2	31/47 (70.0, 50.7–79.1)	1/11 (0.9, 0.2–41.3)	14/58 (24.1, 13.9–37.2)	4/5 (80.0, 28.4–99.5)	2/5 (40.0, 5.3–85.3)	4/6 (66.7, 22.3–95.7)	56/132 (42.4, 33.9–51.3)
Showering at the end of the shift	Phase 1	16/68 (23.5, 14.1–35.4)	1/12 (8.3, 0.2–38.5)	59/115 (51.3, 41.8–60.7)	9/14 (64.3, 35.1–87.2)	10/16 (62.5, 35.4–84.8)	2/6 (33.3, 4.3–77.7)	97/231 (42.0, 35.5–48.6)
	Phase 2	3/47 (6.4, 1.3–17.5)	0/11 (0.0, 0.0–28.5)	36/58 (62.1, 48.4–74.5)	1/5 (20.0, 0.5–71.6)	4/5 (80.0, 28.4–99.5)	2/6 (33.3, 4.3–77.7)	46/132 (34.8, 26.8–43.6)
Showering if PPE breach	Phase 1	10/68 (14.7, 7.3–25.4)	2/12 (16.7, 2.1–48.4)	**3/115 (2.6, 0.5–7.4)**	1/14 (7.1, 0.2–33.9)	0/16 (0.0, 0.0–20.6)	0/6 (0.0, 0.0–45.9)	**16/231 (6.9, 4.0–11.0)**
	Phase 2	13/47 (27.7, 15.6–42.6)	1/11 (0.9, 0.2–41.3)	**22/58 (37.9, 25.5–51.6)**	0/5 (0.0, 0.0–52.2)	2/5 (40.0, 5.3–85.3)	3/6 (50.0, 11.8–88.2)	**41/132 (31.1, 23.3–39.7)**

The values listed in bold represent no overlap of 95% CI between phase 1 and phase 2 and are significant results.
CI = confidence interval; PPE = personal protective equipment.

demonstrated a significant increase from phase 1 to phase 2 (51.9% in phase 1 [95% CI: 45.3–58.5] versus 85.6% in phase 2 [95% CI: 78.4–91.1]). Very few ICUs reported unchanged visitation policies in phase 2 (6/132, 4.5%) (Tables 1 and 2).

3.1.7. PPE reuse

Policies regarding PPE reuse were explored only in the phase 2 survey. Fifty-one percent (67/131) of ICUs reported reuse of face shields after washing with soap and water, whereas 31% (41/131) of ICUs were advised to reuse N95 masks (Supplementary Table 3).

4. Discussion

This multinational follow-up survey was conducted to explore if there were any changes to PPE preparedness reported by intensivists from six Asia-Pacific countries for the COVID-19 pandemic. The use of N95 masks in ICUs at all times significantly increased in phase 2. There was an overall improvement in general PPE preparedness across ICUs in the six countries, particularly in the areas of individual PPE practices, visitation policies, PPE stocks, and HCWs' perceptions of safety. No statistically significant differences were observed between the two phases in PPE training, except for donning and doffing, wherein there was a significant reduction in training. Implementation of a buddy system was similar between the two phases. There was an increased uptake of noninvasive oxygenation therapies within most ICUs, preferably in negative-pressure rooms with overflow and a shift away from invasive mechanical ventilation.

The PPE practices for managing patients with COVID-19 have improved since the start of the pandemic, which is bolstered by

Table 2
Management and training strategies for patients with COVID-19 and perceptions of safety in HCWs.

Training and other other managements		Australia, n/N (%, 95% CI)	Hong Kong, n/N (%, 95% CI)	India, n/N (%, 95% CI)	New Zealand, n/N (%, 95% CI)	Philippines, n/N (%, 95% CI)	Singapore, n/N (%, 95% CI)	Total, n/N (%, 95% CI)
Regular training for aerosol-generating activities in patients with COVID-19								
Tracheal intubation training	Phase 1	40/68 (58.8, 46.2–70.6)	4/12 (13.6, 9.9–65.1)	21/115 (18.3, 11.7–26.5)	11/14 (78.6, 49.2–95.3)	4/16 (25.0, 7.3–52.4)	3/6 (50.0, 11.8–88.2)	83/231 (35.9, 29.7–42.5)
	Phase 2	27/46 (58.7, 43.2–73.0)	2/11 (18.2, 2.3–51.8)	7/58 (12.1, 5.0–23.3)	1/5 (20.0, 0.5–71.6)	1/5 (20.0, 0.5–71.6)	3/6 (50.0, 11.8–88.2)	41/131 (31.3, 23.5–40.0)
Intrahospital transport training	Phase 1	15/68 (22.1, 12.9–33.8)	1/12 (8.3, 0.2–38.5)	19/115 (16.5, 10.3–24.6)	7/14 (50.0, 23.0–77.0)	4/16 (25.0, 7.3–52.4)	1/6 (16.7, 0.4–64.1)	47/231 (20.3, 15.3–26.1)
	Phase 2	14/47 (29.8, 17.3–44.9)	0/11 (0.0, 0.0–28.5)	10/58 (17.2, 8.6–29.4)	0/5 (0.0, 0.0–52.2)	2/5 (40.0, 5.3–85.3	3/6 (50.0, 11.8–88.2)	29/132 (22.1, 15.4–30.2)
PPE donning and doffing training	Phase 1	54/68 (79.4, 67.9–88.3)	9/12 (75.0, 42.8–94.5)	48/115 (41.7, 32.6–51.3)	14/14 (100.0, 76.8–100.0)	10/16 (62.5, 35.4–84.8)	4/6 (66.7, 22.3–95.7)	**139/231 (60.2, 53.5–66.5)**
	Phase 2	30/46 (65.2, 49.8–78.6)	5/11 (45.5, 16.7–76.6)	19/58 (32.8, 21.0–46.3)	0/5 (0.0, 0.0–52.2)	1/5 (20.0, 0.5–71.6)	3/6 (50.0, 11.8–88.2)	**58/131 (44.3, 35.6–53.2)**
PPE waste disposal training for cleaners	Phase 1	25/68 (36.8, 25.4–49.3)	4/12 (13.6, 9.9–65.1)	43/115 (37.4, 28.5–46.9)	6/14 (42.9, 17.7–71.1)	9/16 (56.3, 29.9–80.2)	2/6 (33.3, 4.3–77.7)	89/231 (38.5, 32.2–45.1)
	Phase 2	12/46 (26.1, 14.3–41.1)	4/11 (36.4, 10.9–69.2)	17/58 (29.3, 18.1–42.7)	1/5 (20.0, 0.5–71.6)	3/5 (60.0, 14.7–94.7)	3/6 (50.0, 11.8–88.2)	40/131 (30.5, 22.8–39.2)
Specialised COVID intubation team	Phase 1	52/68 (76.5, 64.6–85.9)	5/12 (41.7, 15.2–72.3)	69/115 (60.0, 50.4–69.0)	13/14 (92.9, 66.1–99.8)	11/16 (68.8, 41.3–89.0)	2/6 (33.3, 4.3–77.7)	152/231 (65.8, 59.3–71.9)
	Phase 2	39/46 (84.8, 71.1–93.7)	5/11 (45.5, 16.7–76.6)	46/58 (79.3, 66.6–88.8)	4/5 (80.0, 28.4–99.5)	5/5 (100.0, 47.8–100.0)	3/6 (50.0, 11.8–88.2)	102/131 (77.9, 69.8–84.6)
Prone positioning of patients with COVID[a]	Phase 2	15/47 (32%)	0/11 (0%)	8/58 (14%)	0/5 (0%)	1/5 (20%)	2/6 (33%)	26/132 (20%)
Awareness of PPE stock adequacy to manage three patients confirmed with COVID-19 in the ICU for at least 1 week								
Aware of PPE stock and able to care for three patients with COVID for 1 week	Phase 1	**36/68 (52.9, 40.4–65.2)**	11/12 (91.7, 61.5–99.8)	**49/115 (42.6, 33.4–52.2)**	12/14 (85.7, 57.2–98.2)	7/16 (43.8, 19.8–70.1)	5/6 (83.3, 35.9–99.6)	**120/231 (51.9, 45.3–58.5)**
	Phase 2	**40/47 (85.1, 71.7–93.8)**	11/11 (100.0, 71.5–100.0)	**49/58 (84.5, 72.6–92.7)**	4/5 (80.0, 28.4–99.5)	3/5 (60.0, 14.7–94.7)	6/6 (100.0, 54.1–100.0)	**113/132 (85.6, 78.4–91.1)**
Family/NOK visitation								
Remotely, no exceptions	Phase 1	**36/68 (52.9, 40.4–65.2)**	11/12 (91.7, 61.5–99.8)	74/115 (64.3, 54.9–73.1)	13/14 (92.9, 66.1–99.8)	13/16 (81.3, 54.4–96.0)	5/6 (83.3, 35.9–99.6)	**152/231 (65.8, 59.3–71.9)**
	Phase 2	**42/47 (89.4, 76.9–96.5)**	11/11 (100.0, 71.5–100.0)	48/58 (82.8, 70.6–91.4)	4/5 (80.0, 28.4–99.5)	5/5 (100.0, 47.8–100.0)	5/6 (83.3, 35.9–99.6)	**115/132 (87.1, 80.2–92.3)**
Perceptions of safety reported by intensivists (highly agree)								
I feel very safe	Phase 1	20/68 (29.4, 19.0–41.7)	6/12 (50.0, 21.1–78.9)	**26/115 (22.6, 15.3–31.3)**	8/12 (66.7, 34.9–90.1)	1/16 (6.3, 0.2–30.2)	4/6 (66.7, 22.3–95.7)	**65/229 (28.4, 22.6–34.7)**
	Phase 2	25/47 (53.2, 38.1–67.9)	10/11 (90.9, 58.7–99.8)	**36/58 (62.1, 48.4–74.5)**	2/5 (40.0, 5.3–85.3)	1/5 (20.0, 0.5–71.6)	6/6 (100.0, 54.1–100.0)	**80/132 (60.6, 51.7–69.0)**
PPE practice is suboptimal to prevent healthcare worker infection	Phase 1	21/68 (30.9, 20.2–43.3)	0/12 (0.0, 0.0–26.5)	**65/115 (56.5, 47.0–65.7)**	2/12 (16.7, 2.1–48.4)	3/16 (18.8, 4.0–45.6)	0/6 (0.0, 0.0–45.9)	**91/229 (39.7, 33.4–46.4)**
	Phase 2	14/47 (29.8, 17.3–44.9)	1/11 (0.9, 0.2–41.3)	**11/58 (19.0, 9.9–31.4)**	3/5 (60.0, 14.7–94.7)	1/5 (20.0, 0.5–71.6)	0/6 (0.0, 0.0–45.9)	**30/132 (22.7, 15.9–30.8)**
PPE stock is at least 2 months behind	Phase 1	**47/68 (69.1, 56.7–79.8)**	**9/12 (75.0, 42.8–94.5)**	**68/115 (59.1, 49.6–68.2)**	5/12 (41.7, 15.2–72.3)	10/16 (62.5, 35.4–84.8)	1/6 (16.7, 0.4–64.1)	**140/229 (61.1, 54.5–67.5)**
	Phase 2	**6/47 (12.8, 4.8–25.7)**	**1/11 (0.9, 0.2–41.3)**	**5/58 (8.6, 2.9–19.0)**	1/5 (20.0, 0.5–71.6)	0/5 (0.0, 0.0–52.2)	0/6 (0.0, 0.0–45.9)	**13/132 (9.8, 5.3–16.3)**

The values listed in bold represent no overlap of 95% CI between phase 1 and phase 2 and are significant results.
COVID = coronavirus disease; PPE = personal protective equipment; NOK = next of kin; CI = confidence interval; COVID-19 = coronavirus disease 2019; HCW = healthcare worker.
[a] Training for prone positioning of patients with COVID was only asked in phase 2.

various factors. Increased PPE production is one amongst them.[11–14] Across all countries, almost all recommended PPE was used by 80% or more of the respondents in the phase 2 survey. It is encouraging to see an increased use of surface protective measures, such as shoe covers and neck covers, as severe acute respiratory syndrome coronavirus 2 has been shown to cause significant surface contamination, especially in ICUs.[15] The use of N95 masks continued to increase, with 86% of respondents reporting wearing N95/P2 masks at all times, compared with only 54% in phase 1. This was an expected change as the community spread of severe acute respiratory syndrome coronavirus 2 increased. However, internationally, guidelines continue to be inconsistent with regard to the use of masks, with WHO guidelines still recommending N95 masks for AGPs only[16] and societies such as the Australian and New Zealand Intensive Care Society recommending N95 mask use while nursing critically ill patients at all times.[17]

Perceptions of safety in HCWs improved across most countries. There has been a significant push for more PPE production, with many countries expanding local manufacturing of PPE, including using nonmedical manufacturers for PPE production.[12] We found that overall awareness of PPE stock also improved among HCWs. This likely reflects the greater transparency from hospitals and government authorities, which is important for reducing HCWs' fear and anxiety.[18]

Of concern, there was no significant difference in most aspects of HCW training in phase 2 compared with phase 1. This was contrary to the intermediate follow-up study that our group

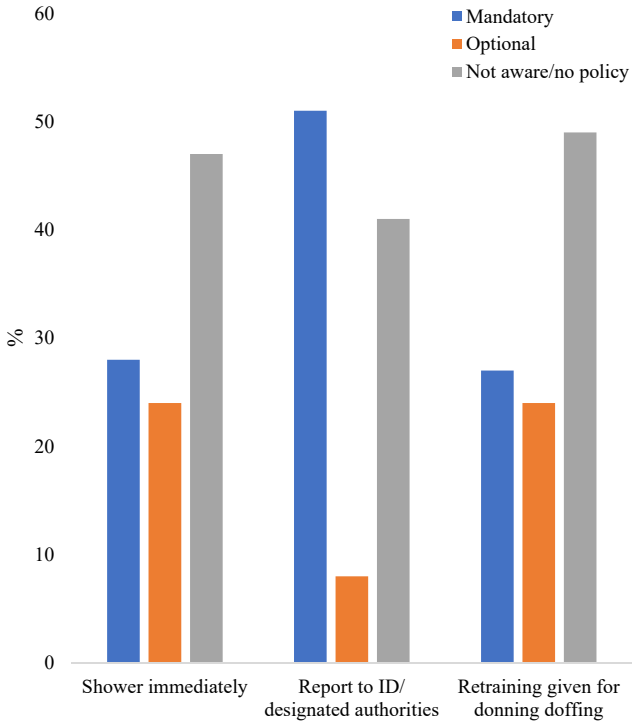

Fig. 3. Measures after PPE breach. PPE = personal protective equipment.

conducted in India 1 month after the initial phase 1 survey, which showed a significant increase in all aspects of HCW training.[19] We postulate the following reasons: either all HCWs were confident about their training[20] or there was a possible waning of training opportunities as the pandemic peaked. Other plausible causes include probable staff attrition, lack of time in their busy ICUs, and PPE fatigue. We observed that less than 50% of the ICUs conducted regular training, with a significant drop in PPE donning and doffing in phase 2. Because inappropriate PPE doffing is associated with increased contamination of HCWs[21] and full training of HCWs reduces the rate of infection in HCW, it is important that ICUs continue to provide regular training and refresher sessions to maintain appropriate PPE practices, familiarity, and confidence among HCWs.[20,21]

Despite societal guideline recommendations,[17,22] low-cost safety measures, such as use of buddy systems, continued to be underused. Furthermore, there was still resistance in implementing fit-testing in HCWs, with a recent large survey identifying that more than half of the survey respondents were fit-tested with N95 masks.[8] Although fit-testing must be part of a respiratory protection program to ensure a safe working environment, there are both legal and moral obligations in implementing these measures.[23] The lack of improvement in HCW training and minimal use of low-cost safety measures warrants further attention from hospitals and policymakers as these simple methods can help reduce infections in HCWs.

Management of PPE breaches needs further attention as 40–50% of respondents reported either not being aware of or not having a formal policy on reporting, showering, or retraining for donning and doffing after a PPE breach (Fig. 3). Although there was an

Table 3
Noninvasive oxygenation therapies.

Noninvasive oxygen therapies			Australia, n/N (%, 95% CI)	Hong Kong, n/N (%, 95% CI)	India, n/N (%, 95% CI)	New Zealand, n/N (%, 95% CI)	Philippines, n/N (%, 95% CI)	Singapore, n/N (%, 95% CI)	Total, n/N (%, 95% CI)
Low-flow oxygen <6 L/min	Not an option – will intubate immediately	Phase 1	2/68 (2.9, 0.4–10.2)	0/12 (0.0, 0.0–26.5)	26/115 (22.6, 15.3–31.3)	0/14 (0.0, 0.0–23.2)	3/16 (18.8, 4.0–45.6)	0/6 (0.0, 0.0–45.9)	31/231 (13.4, 9.3–18.5)
		Phase 2	1/47 (2.1, 0.1–11.3)	0/11 (0.0, 0.0–28.5)	5/58 (8.6, 2.9–19.0)	0/5 (0.0, 0.0–52.2)	0/5 (0.0, 0.0–52.2)	0/6 (0.0, 0.0–45.9)	6/132 (4.5, 1.7–9.6)
	Neutral rooms with overflow	Phase 1	32/68 (47.1, 34.8–59.6)	0/12 (0.0, 0.0–26.5)	**57/115 (49.6, 40.1–59.0)**	5/14 (35.7, 12.8–64.9)	6/16 (37.5, 15.2–64.6)	3/6 (50.0, 11.8–88.2)	103/231 (44.6, 38.1–51.2)
		Phase 2	21/47 (44.7, 30.2–59.9)	0/11 (0.0, 0.0–28.5)	**14/58 (24.1, 13.9–37.2)**	2/5 (40.0, 5.3–85.3)	2/5 (40.0, 5.3–85.3)	2/6 (33.3, 4.3–77.7)	41/132 (31.1, 23.3–39.7)
	Negative-pressure rooms with overflow	Phase 1	26/68 (38.2, 26.7–50.8)	3/12 (25.0, 5.5–57.2)	**10/115 (8.7, 4.2–15.4)**	7/14 (50.0, 23.0–77.0)	2/16 (12.5, 1.6–38.3)	0/6 (0.0, 0.0–45.9)	**48/231 (20.8, 15.7–26.6)**
		Phase 2	22/47 (46.8, 32.1–61.9)	1/11 (9.1, 0.2–41.3)	**33/58 (56.9, 43.2–69.8)**	3/5 (60.0, 14.7–94.7)	2/5 (40.0, 5.3–85.3)	3/6 (50.0, 11.8–88.2)	**64/132 (48.5, 39.7–57.3)**
	Negative-pressure rooms only	Phase 1	8/68 (11.8, 5.2–21.9)	9/12 (75.0, 42.8–94.5)	22/115 (19.1, 12.4–27.5)	2/14 (14.3, 1.8–42.8)	5/16 (31.3, 11.0–58.7)	3/6 (50.0, 11.8–88.2)	49/231 (21.2, 16.1–27.1)
		Phase 2	3/47 (6.4, 1.3–17.5)	10/11 (90.9, 58.7–99.8)	4/58 (6.9, 1.9–16.7)	0/5 (0.0, 0.0–52.2)	1/5 (20.0, 0.5–71.6)	1/6 (16.7, 0.4–64.1)	19/132 (14.4, 8.9–21.6)
High-flow nasal cannula oxygenation	Not an option – will intubate immediately	Phase 1	18/68 (26.5, 16.5–38.6)	8/12 (66.7, 34.9–90.1)	**30/115 (26.1, 18.3–35.1)**	1/14 (7.1, 0.2–33.9)	1/16 (6.3, 0.2–30.2)	3/6 (50.0, 11.8–88.2)	**61/231 (26.4, 20.8–32.6)**
		Phase 2	5/47 (10.6, 3.5–23.1)	5/11 (45.5, 16.7–76.6)	**4/58 (6.9, 1.9–16.7)**	0/5 (0.0, 0.0–52.2)	0/5 (0.0, 0.0–52.2)	0/6 (0.0, 0.0–45.9)	**14/132 (10.6, 5.9–17.2)**
	Neutral rooms with overflow	Phase 1	11/68 (16.2, 8.4–27.1)	1/12 (8.3, 0.2–38.5)	41/115 (35.7, 26.9–45.1)	1/14 (7.1, 0.2–33.9)	2/16 (12.5, 1.6–38.3)	1/6 (16.7, 0.4–64.1)	**57/231 (24.7, 19.3–30.8)**
		Phase 2	2/47 (4.3, 0.5–14.5)	0/11 (0.0, 0.0–28.5)	10/58 (17.2, 8.6–29.4)	0/5 (0.0, 0.0–52.2)	1/5 (20.0, 0.5–71.6)	0/6 (0.0, 0.0–45.9)	**13/132 (9.8, 5.3–16.3)**
	Negative-pressure rooms with overflow	Phase 1	17/68 (25.0,15.3–37.0)	2/12 (16.7, 2.1–48.4)	**5/115 (4.3, 1.4–9.9)**	8/14 (57.1, 28.9–82.3)	3/16 (18.8, 4.0–45.6)	1/6 (16.7, 0.4–64.1)	**36/231 (15.6, 11.2–20.9)**
		Phase 2	22/47 (46.8, 32.1–61.9)	0/11 (0.0, 0.0–28.5)	**32/58 (55.2, 41.5–68.3)**	4/5 (80.0, 28.4–99.5)	3/5 (60.0, 14.7–94.7)	1/6 (16.7, 0.4–64.1)	**62/132 (47.0, 38.2–55.8)**
	Negative-pressure rooms only	Phase 1	22/68 (32.3, 21.5–44.8)	1/12 (8.3, 0.2–38.5)	39/115 (33.9, 25.3–43.3)	4/14 (28.6, 8.4–58.1)	10/16 (62.5, 35.4–84.8)	1/6 (16.7, 0.4–64.1)	77/231 (33.3, 27.3–39.8)
		Phase 2	18/47 (38.3, 24.5–53.6)	6/11 (54.5, 23.4–83.3)	10/58 (17.2, 8.6–29.4)	1/5 (20.0, 0.5–71.6)	1/5 (20.0, 0.5–71.6)	5/6 (83.3, 35.9–99.6)	41/132 (31.1, 23.3–39.7)

Table 3 (*continued*)

Noninvasive oxygen therapies			Australia, n/N (%, 95% CI)	Hong Kong, n/N (%, 95% CI)	India, n/N (%, 95% CI)	New Zealand, n/N (%, 95% CI)	Philippines, n/N (%, 95% CI)	Singapore, n/N (%, 95% CI)	Total, n/N (%, 95% CI)
Noninvasive ventilation	Not an option – will intubate immediately	Phase 1	**31/68 (45.6, 33.5–58.1)**	10/12 (83.3, 51.6–97.9)	**44/115 (38.3, 29.4–47.8)**	4/14 (28.6, 8.4–58.1)	11/16 (68.8, 41.3–89.0)	5/6 (83.3, 35.9–99.6)	**105/231 (45.5, 38.9–52.1)**
		Phase 2	**9/47 (19.1, 9.1–33.3)**	8/11 (72.7, 39.0–94.0)	**6/58 (10.3, 3.9–21.1)**	2/5 (40.0, 5.3–85.3)	1/5 (20.0, 0.5–71.6)	2/6 (33.3, 4.3–77.7)	**28/132 (21.2, 14.6–29.2)**
	Neutral rooms with overflow	Phase 1	7/68 (10.3, 4.2–20.1)	0/12 (0.0, 0.0–26.5)	34/115 (29.6, 21.4–38.8)	1/14 (7.1, 0.2–33.9)	1/16 (6.3, 0.2–30.2)	1/6 (16.7, 0.4–64.1)	**44/231 (19.0, 19.2–24.7)**
		Phase 2	1/47 (2.1, 0.1–11.3)	0/11 (0.0, 0.0–28.5)	9/58 (15.5, 7.3–27.4)	0/5 (0.0, 0.0–52.2)	1/5 (20.0, 0.5–71.6)	0/6 (0.0, 0.0–45.9)	**11/132 (8.3, 4.2–14.4)**
	Negative-pressure rooms with overflow	Phase 1	7/68 (10.3, 4.2–20.1)	1/12 (8.3, 0.2–38.5)	**5/115 (4.3, 1.4–9.9)**	7/14 (50.0, 23.0–77.0)	1/16 (6.3, 0.2–30.2)	0/6 (0.0, 0.0–45.9)	**21/231 (9.1, 5.7–13.6)**
		Phase 2	10/47 (21.3, 10.7–35.7)	0/11 (0.0, 0.0–28.5)	**25/58 (43.1, 30.2–56.8)**	3/5 (60.0, 14.7–94.7)	2/5 (40.0, 5.3–85.3)	0/6 (0.0, 0.0–45.9)	**40/132 (30.3, 22.6–38.9)**
	Negative-pressure rooms only	Phase 1	23/68 (33.8, 22.8–46.3)	1/12 (8.3, 0.2–38.5)	32/115 (27.8, 19.9–37.0)	2/14 (14.3, 1.8–42.8)	3/16 (18.8, 4.0–45.6)	0/6 (0.0, 0.0–45.9)	61/231 (26.4, 20.8–32.6)
		Phase 2	27/47 (57.4, 42.2–71.7)	3/11 (27.3, 6.0–61.0)	15/58 (25.9, 15.3–39.0)	0/5 (0.0, 0.0–52.2)	1/5 (20.0, 0.5–71.6)	4/6 (66.7, 22.3–95.7)	50/132 (37.9, 29.6–46.7)

The values listed in bold represent no overlap of 95% CI between phase 1 and phase 2 and are significant results.
CI = confidence interval.

increase in showering after PPE breach, it was only mandated in around 30% of ICUs. It is equally concerning to note that 60% of Indian and Philippine ICUs reported reusing N95 masks, contrary to WHO, Centers for Disease Control and Prevention, and Australian and New Zealand Intensive Care Society recommendations, and that these areas may display a need for additional N95 masks,[16,17,24]

In the early stages of the pandemic, there was hesitancy with using noninvasive oxygenation therapies owing to risk of aerosol transmission, with preference for early intubation. Intubation in patients with COVID-19 has been associated with increased barotrauma and mortality.[25] Studies have found HFNO to be at low risk of bioaerosol dispersion contrary to previous concerns and effective in reducing the need for intubation and mechanical ventilation.[26–29] Hence, it is encouraging to see that in phase 2, there was an increase in their use, particularly NIV and HFNO, shifting away from early intubation, which was witnessed in phase 1. Appropriate PPE is essential to balance against the unknown risk of airborne transmission.[26] With the increased production of PPE and improved PPE practices, it has likely helped to make these forms of noninvasive oxygenation therapies a safer option for use in ICUs than was initially possible.

The study had several strengths. First, we included a range of ICUs in various countries at varying stages of the COVID-19 pandemic, which allowed for assessment of PPE preparedness across diverse landscapes with differing COVID-19 burdens. Second, a robust process was followed to design and validate the survey questionnaire. Third, the phase 2 survey, distributed 5 months after the initial survey, provided sufficient time for changes in PPE practices to be implemented by hospitals, and thus, changes could be assessed effectively.

There were several limitations. Although the study overall had a moderate mean response rate of 63%, there was marked variation in response rates of individual countries. Particularly, the Philippines and NZ both had low response rates and small sample sizes, which may restrict applicability of the results there. Although we sent the follow-up survey to the same ICUs that responded in phase 1 to ensure consistency between the two phases, we were not sure what fraction of response came from the same person in that ICU between the first and second survey. Inherent to any survey, response bias may be present. The responses were self-reported and were not further independently checked to confirm if they aligned with their ICU protocols/practices. Although some additional AGPs such as prone positioning were added in the phase 2 survey, there were still many AGPs including cardiopulmonary resuscitation, tracheostomy, and bronchoscopy that were not assessed, mainly to keep response time manageable. Further research into rates of infection in HCW may be beneficial to determine this association.

5. Conclusion

This follow-up survey found that ICUs in the six Asia-Pacific countries reported improvements in their overall PPE preparedness. There was a reported increased uptake in PPE practices, awareness regarding PPE stocks, and implementation of more refined visitation policies, resulting in an improved perception of safety amongst HCWs. There was a reported trend towards increased use of less invasive respiratory therapies and shift away from early invasive mechanical ventilation. However, the reported uptake of HCW training and implementation of low-cost safety measures continued to be low, and awareness of PPE breach management polices was suboptimal. We suggest that further attention be given to HCW training and implementation of inexpensive measures to help reduce rates of infection in HCWs.

CRediT authorship contribution statement

Navya Gullapalli: Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Zheng Jie Lim**: Data curation, Formal analysis, Software, Writing – review & editing. **Kollengode Ramanathan**: Conceptualisation, Methodology, Writing – review & editing. **Shailesh Bihari**: Writing – review & editing. **Jumana Haji**: Writing – review & editing. **Kiran Shekar**: Writing – review & editing. **Wai Tat Wong**: Writing – review & editing. **Arvind Rajamani**: Conceptualisation, Methodology, Writing – review & editing. **Ashwin Subramaniam**: Conceptualisation, Methodology, Data curation, Supervision, Project administration, Writing – original draft, Writing – review & editing

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aucc.2021.02.007.

References

[1] Nguyen LH, Drew DA, Joshi AD, Guo CG, Ma W, Mehta RS, et al. Risk of COVID-19 among frontline healthcare workers and the general community: a prospective cohort study. medRxiv 2020.

[2] Wang J, Zhou M, Liu F. Reasons for healthcare workers becoming infected with novel coronavirus disease 2019 (COVID-19) in China. J Hosp Infect 2020;105:100–1.
[3] Smith P. Covid-19 in Australia: most infected health workers in Victoria's second wave acquired virus at work. BMJ 2020;370. m3350.
[4] Rajamani A, Subramaniam A, Shekar K, Haji J, Luo J, Bihari S, et al. Personal protective equipment preparedness in Asia-Pacific intensive care units during the coronavirus disease 2019 pandemic: a multinational survey. Aust Crit Care 2021;34:135–41.
[5] Organisation WH. Weekly epidemiological update - 7 September 2020. 2020.
[6] Health.givt.nz. COVID-19: source of cases. Ministry of Health; 2021.
[7] WHO. Singapore coronavirus disease 2019 (COVID-19) situation report. Weekly report for the week ending 6 september 2020, report 3. 2020.
[8] Tabah A, Ramanan M, Laupland KB, Buetti N, Cortegiani A, Mellinghoff J, et al. Personal protective equipment and intensive care unit healthcare worker safety in the COVID-19 era (PPE-SAFE): an international survey. J Crit Care 2020;59:70–5.
[9] De Iaco G, Puro V, Fusco FM, Schilling S, Maltezou HC, Brouqui P, et al. Personal protective equipment management and policies: European Network for Highly Infectious Diseases data from 48 isolation facilities in 16 European countries. Infect Control Hosp Epidemiol 2012;33:1008–16.
[10] Organisation WH. Rational use of personal protective equipment for coronavirus disease (COVID-19): interim guidance. WHO; 2020.
[11] Burki T. Global shortage of personal protective equipment. Lancet Infect Dis 2020;20:785–6.
[12] Park C-K, Kim K, Roth S. Global shortage of personal protective equipment amid COVID-19: supply chains, bottlenecks, and policy implications. Asian Development Bank 2020.
[13] Feinmann J. PPE: what now for the global supply chain? BMJ 2020;369. m1910.
[14] Nazmul Karim. Major interventions needed to meet global PPE demand. Health Europa; 2020.
[15] Guo ZD, Wang ZY, Zhang SF, Li X, Li L, Li C, et al. Aerosol and surface distribution of severe acute respiratory syndrome coronavirus 2 in hospital wards, Wuhan, China, 2020. Emerg Infect Dis 2020;26:1583–91.
[16] Organisation WH. Advice on the use of masks in the context of COVID-19: interim guidance, 5 June 2020. 2020.
[17] ANZICS. COVID-19 guidelines: version 3. 2020.
[18] Spalluto LB, Planz VB, Stokes LS, Pierce R, Aronoff DM, McPheeters ML, et al. Transparency and trust during the coronavirus disease 2019 (COVID-19) pandemic. J Am Coll Radiol 2020;17:909–12.
[19] Haji JY, Subramaniam A, Kumar P, Ramanathan K, Rajamani A. State of personal protective equipment practice in Indian intensive care units amidst COVID-19 pandemic: a nationwide survey. Indian J Crit Care Med 2020;24:809–16.
[20] Barratt R, Shaban RZ, Gilbert GL. Characteristics of personal protective equipment training programs in Australia and New Zealand hospitals: a survey. Infect Dis Health 2020;25:253–61.
[21] Suen LKP, Guo YP, Tong DWK, Leung PHM, Lung D, Ng MSP, et al. Self-contamination during doffing of personal protective equipment by healthcare workers to prevent Ebola transmission. Antimicrob Resist Infect Contr 2018;7:157.
[22] NHMRC. Australian guidelines for the prevention and control of infection in healthcare. 2019. p. 2020.
[23] Veness BCK, Baxter N. Respirator fit-testing: busting the myths. MJA InSight+ 2002. https://www.nhmrc.gov.au/about-us/publications/australian-guidelines-prevention-and-control-infection-healthcare-2019.
[24] Prevention CoDCa. Implementing filtering facepiece respirator (FFR) reuse, including reuse after decontamination, when there are known shortages of N95 respirators. CDC; 2020.
[25] Lim ZJ, Subramaniam A, Reddy MP, Blecher G, Kadam U, Afroz A, et al. Case fatality rates for COVID-19 patients requiring invasive mechanical ventilation: a meta-analysis. Am J Respir Crit Care Med 2020;203(1).
[26] Agarwal A, Basmaji J, Muttalib F, Granton D, Chaudhuri D, Chetan D, et al. High-flow nasal cannula for acute hypoxemic respiratory failure in patients with COVID-19: systematic reviews of effectiveness and its risks of aerosolization, dispersion, and infection transmission. Can J Anaesth 2020;67:1217–48.
[27] Guy T, Creac'hcadec A, Ricordel C, Sale A, Arnouat B, Bizec JL, et al. High-flow nasal oxygen: a safe, efficient treatment for COVID-19 patients not in an ICU. Eur Respir J 2020;56.
[28] Rochwerg B, Granton D, Wang DX, Helviz Y, Einav S, Frat JP, et al. High flow nasal cannula compared with conventional oxygen therapy for acute hypoxemic respiratory failure: a systematic review and meta-analysis. Intensive Care Med 2019;45:563–72.
[29] Zhao H, Wang H, Sun F, Lyu S, An Y. High-flow nasal cannula oxygen therapy is superior to conventional oxygen therapy but not to noninvasive mechanical ventilation on intubation rate: a systematic review and meta-analysis. Crit Care 2017;21:184.