

Powered Air Purifying Respirators (PAPR) for the protection of surgeons during operative tasks: a user perspective assessment

Editor

The unfolding COVID-19 pandemic has challenged surgical care where aerosol-generating operations may expose the surgical team^{1,2,3}. Optimization of theatre airflow management and the application of smoke evacuation devices have been recommended and some personal protective equipment may remain for the foreseeable future^{1,2,3}. WHO guidelines advise well-fitting respirators (for example FFP2/3 or N95 masks) for surgical teams as the minimum where there is exposure risk. These disposable masks are becoming scarce and may not offer the required protection especially when poorly fitted. Powered Air Purifying Respirators (PAPR) are another type of respiratory protection that are validated to offer higher respiratory protection

by regulatory bodies (2.5–100x Airway Protection Factor versus N95 masks). These respirators feature a waist-mounted battery-powered pump that blows filtered air into a hood and are reusable. These devices are widely used in other industries but haven't been formally assessed for operating room teams.

As part of a validation exercise, a frontline clinical user perspective assessment was performed of donated PAPR under operating conditions in high-fidelity simulation environments. Scott Tornado (3 M) PAPR with both half (FH1) and full (FH2) hoods was tested by 46 clinicians (36 surgeons, six anaesthetists and four nurses) without prior PAPR experience in elective and emergency general surgery (open and laparoscopy), plastics and reconstructive surgery and head and neck/dental surgery simulations with subjective and objective evaluation. Initially, surgeons in PAPR carried out both laparoscopic and open tasks individually and in pairs including

simulated minimal access appendectomy and porcine laparotomy (involving splenectomy, cholecystectomy and bowel resection/anastomosis) over 90–120 mins. Thereafter, complete operative SIM-MAN simulation was performed with four full specialty teams all wearing PAPR, specifically laparoscopic appendectomies (two teams), tracheostomy and cleft palate repair with dental extraction (*Fig. 1*). Subjective confidence, comfort and communications scores were collected at fixed intervals using established, adopted and designed methodology (*Appendix S1*). Collaborative team working was also assessed objectively, including an unexpected challenge during scenarios by planned telephone interruption. Social distancing was observed.

PAPR was well accepted regardless of hood type and all tasks were completed within the allocated time (*Table 1*). There was no temporal deterioration of scores. Confidence in PAPR use

Fig. 1 Photographs showing (a) the two mask types (FH1 and FH2, both with soft-head cradles, neoprene chin seals and clear full-face visors with down-view panels certified to EN12941 TH3, EN166 1F) as well as PAPR use in simulated settings. Participants (b) scrubbing, (c) performing laparoscopic box tasks both individually and in pairs and (c) in full team operating room simulation.



Table 1 Mean values (\pm SD) for measured subjective perception scores (average of all readings) including by clinical role. FH1 denotes half mask while FH2 denotes full mask. Surg denotes surgeons and anaes denotes Anaesthesiologists. *P* values indicate statistical differences between combined means between masks (Mann–Whitney *U* test) and between clinical roles (Kruskal–Wallis test)

Measured score	Mask	Assessment 1 Laparoscopic technical skills (<i>n</i> = 14, 90 mins, FH1 & FH2)		Assessment 2 Laparotomy (<i>n</i> = 4, 120 mins, FH2 only)		Assessment 3 Theatre simulation (<i>n</i> = 25, FH1 & FH2)			
		Mean \pm SD	<i>P</i>	Mean \pm SD	Mean \pm SD	<i>P</i> value	Cohort	Mean \pm SD	<i>P</i>
		Thermal sensation -3 (hot) to +3 (cold)	FH1	0.46 \pm 0.59		-	-1.07 \pm 1.14		Surg
	FH2	-0.50 \pm 1.10	*0.002	0.13 \pm 0.45	-0.64 \pm 0.93	0.329	Anaes	-1.00 \pm 0.93	*0.003 ^a
							Nurses	-1.60 \pm 0.70	
4-point thermal comfort	FH1	1.08 \pm 0.28		-	1.36 \pm 0.63		Surg	1.10 \pm 0.32	
1 (comfortable) to 4 (very uncomfortable)	FH2	1.67 \pm 0.69	*0.001	1.00 \pm 0.00	1.14 \pm 0.36	0.511	Anaes	1.13 \pm 0.35	0.192
							Nurses	1.50 \pm 0.71	
Perception of breathing	FH1	1.33 \pm 0.48		-	1.50 \pm 0.76		Surg	1.00 \pm 0.00	
1 (not noticeable) to 7 (intolerable)	FH2	1.78 \pm 1.06	0.160	1.29 \pm 0.46	1.36 \pm 0.50	0.839	Anaes	1.88 \pm 0.83	*0.012 ^b
							Nurses	1.50 \pm 0.53	
Borg rating of perceived exertion	FH1	6.90 \pm 1.23		-	7.75 \pm 1.67		Surg	7.60 \pm 2.46	
6 (no exertion at all) to 20 (maximal exertion)	FH2	8.11 \pm 2.30	*0.047	6.25 \pm 0.57	8.11 \pm 2.29	0.839	Anaes	8.50 \pm 1.77	0.444
							Nurses	7.80 \pm 1.67	
Eye dryness	FH1	-0.04 \pm 0.20		-	-0.36 \pm 0.63		Surg	-0.10 \pm 0.32	
-3 (very dry) to +3 (very wet)	FH2	-0.33 \pm 0.49	*0.013	0.00 \pm 0.00	-0.57 \pm 0.94	0.701	Anaes	-0.75 \pm 1.16	0.162
							Nurses	-0.60 \pm 0.70	
Ease of communication	FH1	2.46 \pm 0.59		-	2.00 \pm 0.00		Surg	1.60 \pm 0.52	
0 (impossible) to 4 (easier than normal)	FH2	2.22 \pm 0.73	0.304	1.96 \pm 0.36	1.43 \pm 0.51	*0.009	Anaes	1.88 \pm 0.35	0.449
							Nurses	1.70 \pm 0.48	
Listening effort	FH1	3.00 \pm 0.78		-	2.14 \pm 0.86		Surg	1.80 \pm 0.79	
0 (nothing understood) to 4 (no effort)	FH2	2.83 \pm 0.92	0.581	2.04 \pm 0.81	1.71 \pm 0.73	0.210	Anaes	2.25 \pm 0.89	0.432
							Nurses	1.80 \pm 0.79	

*Statistically significant results ($P < 0.05$). Statistically significant *P* value (Mann–Whitney *U* test) for ^asurgeons *versus* nurses with respect to thermal sensation score and for ^bsurgeons *versus* anaesthesiologists for perception of breathing.

significantly improved after assessment (postop median score of 4/5 versus 3 pre-test, $P = 0.002$, Sign Test). FH1 hoods scored best for comfort and communication. Surgeons reported less heat and breathing impact than anaesthesiologists and nurses. Qualitative comments were generally positive with users feeling 'protected' and 'safe'. Pumps alarmed when gowns obstructed the inflow and the fixed length tubing impacted shorter individuals' gowning and teams spatially with respect to sterility but these were manageable. Conventional stethoscopes and loupes could not be used. Alongside ongoing emergency and time-critical surgery,

surgical services now need resumption⁵ including address of the 'third wave' of procedure backlog. PAPR may be fit for surgical settings if needed with local approval and adequate training.



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Conflicts of Interest

None of the authors have conflicts of interest directly related to this study.

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Supporting information

Additional supporting information can be found online in the Supporting Information section at the end of the article.