Original articles

Exploring the use of full-face masks for ventilation in dive rescue

Elizabeth A Blizzard[1,2,3], Andrew A Grandin[2,3,4,5], Dalelynn Sims[6]

[1] *Rutgers New Jersey Medical School, Newark, New Jersey, USA*
[2] *Capital Health Life Support Training Center, Pennington, New Jersey, USA*
[3] *Grand Ideas Medical Consulting, Burlington, New Jersey, USA*
[4] *Capital Health Emergency Medical Services, Pennington, New Jersey, USA*
[5] *ChristianaCare LifeNet, New Jersey, USA*
[6] *Brunswick SCUBA, Freeman, Virginia, USA*

Corresponding author: *Elizabeth Blizzard, 43 Bertrand Dr, Princeton, NJ 08540, USA*
ORCiD: *0009-000 2-3070-8811*
eab318@njms.rutgers.edu

Keywords
Diving medicine; Diving research; First aid; Life support; Rescue; Resuscitation

Abstract
(Blizzard EA, Grandin AA, Sims D. Exploring the use of full-face masks for ventilation in dive rescue. Diving and Hyperbaric Medicine. 2026 31 March;56(1):2−7. doi: 10.28920/dhm56.1.2-7. PMID: 41875436.)
Introduction: Early oxygenation is essential in a non-breathing scuba accident victim, but the need to exclude water has thus far prevented underwater ventilation, causing significant delay. The full-face mask (FFM) is a potential solution, but its safety and feasibility in this context has not been established. This is a preliminary study into the utility of FFMs for underwater ventilation.
Methods: The tidal volume and peak inspiratory pressure delivered by the OTS Guardian and Neptune III FFMs were measured using a RespiTrainer Advance Airway Management Trainer and an open circuit scuba system. Ventilations were tested with varying lengths of purge valve depression and degrees of tightness of the FFM. A tidal volume of 350–560 mL was considered ideal. Thresholds considered to be high risk were 700 mL for volutrauma and peak inspiratory pressure > 3.4 kPa for barotrauma.
Results: In all trials, the delivered pressure remained well below the 3.4 kPa threshold. The delivered volume was consistently less than 700 mL in at least one trial condition per FFM, although this required the fastest possible release of the Guardian purge valve without maximal mask tightening. The Neptune remained below 700 ml regardless of technique but required a one second purge valve depression to deliver sufficient volume (> 350 mL).
Conclusions: Recommendations need to be tailored to specific masks styles or brands. However, this form of ventilation could be feasible. Our findings are most directly applicable to ventilation at the surface. Further testing of these and other FFMs in simulation at depth will be necessary to evaluate the masks' use for ventilation. These results merit further investigation.

Introduction

Drowning is generally listed as the most common cause of death in diving-related fatalities.[1,2] In these cases, hypoxaemia is the leading cause of cardiac arrest. Because of this, early treatment of hypoxia is extremely important, and in-water ventilations may be beneficial once the victim reaches the surface.[3–6] In the past this has been accomplished via mouth-to-mouth, mouth-to-pocket mask, or mouth-to-snorkel methods.[4–6]

However, diving accidents may present several scenarios where these methods are insufficient. In military diving and technical diving with overhead environments or decompression, it may not be feasible to return the victim to the surface in time to prevent irreversible brain damage and death from hypoxia.[7] Public safety and commercial divers also frequently wear full face masks (FFMs) due to due to water conditions, and could benefit from the ability to ventilate without risk of contamination both underwater and at the surface.[7] Currently recommended surface ventilation techniques can be difficult to achieve, especially in rough water conditions.

The possibility of delivering ventilation underwater has already been investigated with conventional resuscitation equipment used outside of diving. Mask ventilators, laryngeal tubes, and endotracheal tubes were all found to be unsuccessful, generally due to issues with aspiration and inadequate seals, especially during device placement.[7,8] FFMs provide a potential solution to these problems. These masks cover the mouth and nose of the diver and seal tightly to the face. This provides the unique advantage that they are likely to be found correctly positioned on an unconscious diver. The mask regulators have purge valves that deliver air forcefully into the mask, usually with the intention of clearing water that has entered the mask. This study evaluated the use of this valve to deliver ventilations.

The only prior study on the use of FFMs for ventilation looked at the Interspiro MK II.[7] This mask initially provided satisfactory ventilation but eventually caused large leaks that lead to massive water entry into the airway. The Interspiro MK II is just one of numerous FFMs available, so further study is required to see if other models might be able to overcome this issue.

This study evaluated two FFMs in a dry environment to determine if they could be a feasible way of delivering ventilation.

Methods

EQUIPMENT CONFIGURATION

The study was conducted using a RespiTrainer Advance Airway Management Trainer (IngMar Medical, Pittsburgh, USA). This mannequin monitors the respiratory rate delivered as well as the tidal volume and peak pressure for each breath (with a breath being defined as the volume delivered by one purge valve depression). The mannequin was factory calibrated by the manufacturer with respiratory mechanics set to a compliance of 50 $mL \cdot cmH_2O^{-1}$ and a resistance of 5 $cmH_2O \cdot L^{-1} \cdot s^{-1}$.[9] A scuba tank supplied compressed air to the FFM, which was applied to the mannequin head. The same person used the purge valve to ventilate the mannequin in all trials. The person providing ventilations was not able to observe the readings on the computer connected to the mannequin.

The mannequin was ventilated using two different FFMs, the Guardian (Ocean Technology Systems, California, USA) (OTS) and the Neptune III (Ocean Reef Group, Genova, Italy). At first, ventilations were delivered using the fastest possible press and release of the purge valve. Next, the purge valve was held for one second and released. The mannequin was ventilated at a rate of one breath every six seconds. Each trial lasted two minutes. In some cases, breaths were delivered that were too small for the mannequin to record. This resulted in fewer data points in some trials.

After completing initial trials, there was concern that the masks had been tightened too much on the mannequin and did not reflect how an actual diver would wear them. To account for this, two additional trials were performed. For each mask, the trial was repeated using the ventilation technique that had given the best results previously. The mask for these trials was tightened according to manufacturer recommendations, just enough that the mask seemed capable of excluding water.

OUTCOME MEASURES AND ANALYSIS

The outcome measures were tidal volumes and peak inspiratory pressures as recorded by the RespiTrainer manikin. Average and standard deviations of each outcome measure were calculated. Google Sheets was used for data analysis and graph generation.

To be safe and effective, purge valve depressions must deliver an adequate tidal volume without causing lung injury. Typically, a tidal volume of 5–8 $mL \cdot kg^{-1}$ of ideal body weight is recommended to meet this goal. Ideal body weight is calculated based on height and gender as suggested by Devine and does not vary in the adult population as much as actual body weight.[10] For each centimeter of height, ideal body weight changes by 0.91 kg. The FFM was expected to deliver a target tidal volume of 350–560 ml based on a male with height of 175 cm and ideal body weight of 70 kg.[9]

Although 5–8 $mL \cdot kg^{-1}$ of ideal body weight is the typical recommended range, it can be safe to exceed this range for patients without significant lung disease. For these patients, volumes greater than 10 $mL \cdot kg^{-1}$ have been shown to be associated with volutrauma and barotrauma.[11] Divers would generally be expected to have relatively healthy lungs and could likely tolerate this 10 $mL \cdot kg^{-1}$ cutoff, which would be 700 mL for the 70 kg ideal body weight adult. Therefore, the FFM should ideally deliver tidal volumes of 350–560 mL though not exceeding 700 mL.

The pressure at which ventilations are delivered also has the potential to cause injury. Previous studies have found that a peak inspiratory pressure greater than 3.4 kPa (35 cmH_2O) increases the risk of pneumothorax or mediastinal emphysema, although some have suggested that peak inspiratory pressures closer to 4 or 5 kPa might be safe.[12] For ventilations given underwater, air in the pleural space or mediastinum would be particularly detrimental as expansion during ascent could cause life threatening compression of the heart and great vessels.[13] Therefore, the more conservative upper threshold of 3.4 kPa was chosen for this study.

Results

Ultimately, both masks were capable of delivering an average tidal volume within the target range of 350–560 mL (Table 1). However, the technique required to do this varied between the masks. For the Guardian, ventilations were appropriate when the purge valve was quickly pressed and released, and when it was depressed for one second, they were excessive. For the Neptune III, ventilations were adequate when given for one second, but too small when the purge valve was pressed for as short a time as possible (Table 1).

Table 1

Results from ventilations delivered by the full-face masks in various trials; SD – standard deviation

Full face mask	Ventilation length	Mask condition	Mean tidal volume (mL) (range, SD)	Mean pressure (kPa) (range, SD)
Neptune III	Shortest possible	Tight	276 (245–322, 33)	0.5 (0.5–0.6, 0.08)
	1s	Tight	500 (375–588, 50)	1.0 (0.8–1.1, 0.09)
	1s	Loose	463 (395–517, 37)	0.9 (0.8–1.0, 0.07)
Guardian	1s	Tight	949 (790–1019, 46)	2.0 (1.6–2.1, 0.1)
	Shortest possible	Tight	604 (344–802, 117)	1.4 (0.8–2.1, 0.3)
	Shortest possible	Loose	416 (321–685, 97)	0.9 (0.5–1.4, 0.2)

Figure 1

Tidal volume results; green lines show ideal volume range (350–560mL); red line indicates the 700 mL high risk threshold for volutrauma; black dots represent individual ventilations; blue hexagons represent mean values. SP – shortest possible purge valve depression; 1s – depression of purge valve for one second

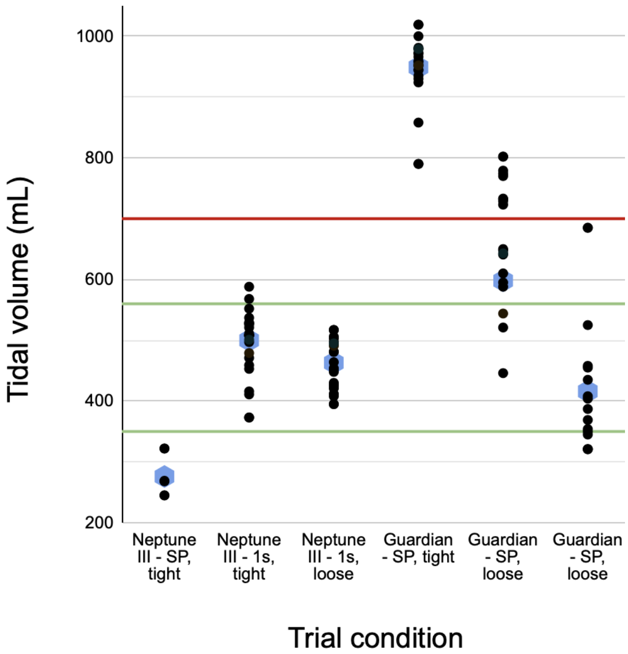
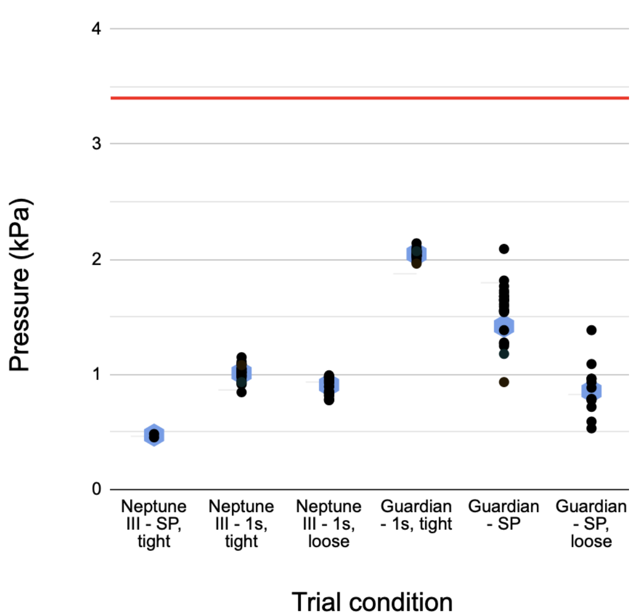


Figure 2

Pressures measured during various ventilation trials; black dots and blue hexagons represent individual and mean values, respectively; red line represents the high-risk threshold for barotrauma (3.4 kPa). SP – shortest possible purge valve depression; 1s – depression of purge valve for one second



In continued testing with fully tightened masks, the masks also differed in reproducibility of the tidal volume delivered. The Neptune III delivered breaths that were more consistent in volume, and they always remained within the target 350–560 mL range when given over one second. By contrast, the Guardian exhibited significant variation. Although the shortest possible depressions of its purge valve provided appropriate average tidal volumes, some breaths were above the target range of 350–560 mL (Figure 1).

Loosening the mask seal did have some effect on whether the mask could deliver volumes within the target range. For both the Guardian and the Neptune III, the average with the looser mask was lower but still above the minimum threshold. All breaths provided by the Neptune III were within the acceptable range. Once again, the Guardian delivered breaths that were more variable, with some that were both too large and too small (Figure 1). However, in this trial, only one breath was above the 560 mL threshold, and all were below the 700 mL threshold.

The peak inspiratory pressure delivered with every breath in each trial was also measured. For all trials, the maximum pressure delivered remained well below the 3.4 kPa limit (Figure 2). Even in the trial where breaths were given from the Guardian over one second and tidal volumes were well over the desired amount; all breaths were well below 3.4 kPa and only slightly above 2 kPa. Outside of this trial, all but one breath was below the 2 kPa threshold.

Discussion

This study evaluated the use of two FFMs for ventilation of divers. Both masks were capable of delivering adequate tidal volumes within the safety norm (< 700 mL). However, both technique and mask tightening needed to be optimal for this.

A large point of concern with using FFMs to ventilate underwater is that inappropriate assisted ventilations may cause pulmonary barotrauma during ascent. For this reason, breaths larger than 700 mL are concerning. Conversely, breaths below 350 mL would be unlikely to harm the patient as long as they did not delay the ascent to the surface. Given these parameters, to be useful for underwater ventilation, a FFM should be able to consistently deliver breaths below the 700 mL threshold.

The Neptune III met this criterion, as all breaths delivered across all trials were below 700 mL. The Guardian was less consistent in this regard. However, it was able to deliver breaths below 700mL in the trial where breaths were given for the shortest possible interval and the mask was only moderately tightened, which may be more realistic in an emergency situation.[14] The user manual for the Guardian recommends against overtightening, as it may cause discomfort and leaking.[15] However, further research is needed to confirm safety of using both masks for emergency underwater ventilation via purge valve. It is also worth noting that these findings were for a person with an ideal body weight of 70 kg, or a height of about 1.75 m in a male. Some divers, particularly females or teenage divers, might have an ideal body weight significantly smaller than this. Additional research will need to consider differing body habitus and how this might affect the safety or efficacy of the studied techniques.

FFMs will require testing in an underwater environment. In a previous study, researchers tested one brand of FFM, the Interspiro MK II, and found that it was not effective in providing ventilations underwater.[7] The authors noted significant issues with seal leakage and found that large amounts of water entered the manikin's airway. They also noted decreasing tidal volumes at depth. This effect was seen only with the FFM and no other ventilation methods tried by the authors. This highlights that underwater conditions may differ from surface testing, and that the results of this study cannot be generalised to underwater use without further testing. It is important to note that the study by Winkler et al., tested only one FFM, and testing of other masks underwater is needed.[7]

The pressure delivered by a mask is also an important safety factor to consider. Both masks used in this study delivered breaths well below the dangerous threshold of 3.4 kPa under both conditions tested. This was likely because of relief and exhaust systems built into the masks that are designed to allow comfortable exhalation and prevent excessive pressure buildup. Despite low peak pressures, the masks were able to effectively inflate the lungs of the manikin used in this study. Given the pressure changes that occur at depth, this may or may not be true for a real person underwater, and further research will be needed on this point. However, these results are encouraging because they suggest that if attempted ventilations are not effective, they are more likely to not provide an effective breath delivery than to cause harm as the gas can vent through the exhalation and relief mechanism as designed. It should be noted that the mannequin is factory-calibrated prior to reaching the end user. As such, calibration was not performed by the authors, and this may impact the accuracy of pressure measurement.

Findings from the Thailand cave rescue using an Interspiro Divator mask suggested that pressures may increase underwater.[14] Van Waart et al., reported that average ventilation pressures at the surface were below 3.4 kPa, although some were as high as 5.31 kPa. At a depth of 0.5 m, pressures of 3.99 kPa were observed.[14] Potentially, additional depth could further increase pressures, resulting in unsafe conditions despite surface results suggesting safety. It should be noted that ventilations in this study were performed by untrained volunteers and demonstrated wide variability. Ventilations may have been influenced by factors such as size, gender, and enthusiasm. This is consistent with findings from another paper investigating use of traditional scuba regulators for ventilation.[16] Further studies will be needed to determine whether full face masks could be used for assisted ventilation of a submerged victim. Additionally, the equipment worn by a diver might impact lung compliance or ability to maintain an open airway. The mannequin in this study included only a head and lungs and could not account for these factors.

Even if further testing reveals that FFMs are not useful for underwater ventilation, they could be helpful for ventilation at the surface. In industrial or public safety diving, FFMs may be worn to protect from contaminated water. In this scenario, it would not be safe for the patient or rescuer to remove masks and deliver ventilations using currently recommended techniques. Assisting ventilation by use of the FFM may be easier than other alternatives even in relatively clean water.

The present study indicates that recommendations for ventilation with a FFM might need to be model specific – the Guardian performed best with shortest possible depressions of the purge valve, while the Neptune III required one second intervals. This complicates recommendation development because there are many different models of FFM, and testing all of them would prove logistically challenging. Even within the same model, maintenance of regulators (or lack thereof) could also impact their performance and ability to deliver consistent volumes or pressures. The OTS Spectrum and ScubaPro in particular introduce wide variability, as they integrate any standard second stage regulator a diver might be using into a FFM via a mouthpiece connector. Given the variety of FFMs available, testing and providing a recommendation tailored to each mask would be extremely difficult if not impossible. Even if this could be done, delivering breaths safely and effectively in an emergency would require the rescuer to know the exact type of mask and regulator used by the patient and look up the proper technique before use. This would necessitate significant planning before an accident and would likely not be feasible for rescuing anyone other than a well-known dive buddy.

The pressure results from this trial might suggest a way to mitigate this issue. Even in trials where tidal volume was very large, pressure remained well below the maximum limit. This was likely because regulators, including those in FFMs, are designed to allow a release of exhaled gas once a certain pressure is reached. When the purge valve is pressed, a diaphragm, valve, or exhalation channel opens at a pressure set by the manufacturer, limiting the pressure inside the mask and airway when attempting ventilations. The pressure limitation by this relief mechanism likely affects the amount of time that the purge valve must be pressed to give a desired tidal volume. Specifically, the Guardian and the Neptune III have distinctly different mechanisms to allow the exhalation of gas through their relief mechanisms. The Guardian uses a valve system, while the Neptune III uses a gradient of pressure between the inside and outside of the mask without a mechanical mechanism. If specific mask design features listed by the manufacturer could be correlated with trial results, it could be possible to provide recommendations for how long to press the purge based on brand or style of mask or regulator. This would allow for more general recommendations that would be easier for divers to implement.

This study has some limitations. It was performed on a mannequin, at the surface, and with one experienced paramedic delivering ventilations. Caution and further study are needed before applying these results to real patients, other rescuers (especially laypeople), or underwater environments. These results should not be used to justify patient use until further testing can be conducted.

Conclusions

Ventilation with a FFM could be feasible, although different techniques were required based on the mask and regulator used. Further testing is necessary before assisted ventilation by FFM can be recommended for a submerged victim. Our current findings are directly applicable to ventilation at the surface, which could be an easier alternative and have particular utility in rough or contaminated water and resource-limited environments. Further testing in-water at depth will be necessary to evaluate the masks' use for ventilation in the underwater environment. After sufficient study, addition of underwater ventilation into dive rescue training could be lifesaving in overhead, military, or decompression diving. These results merit further investigation.

References

1 Casadesús JM, Aguirre F, Carrera A, Boadas-Vaello P, Serrando MT, Reina F. Diving-related fatalities: multidisciplinary, experience-based investigation. Forensic Sci Med Pathol. 2019;15:224–32. doi: 10.1007/s12024-019-00109-2. PMID: 30915609.

2 Tillmans F, editor. DAN annual diving report 2020 edition: A report on 2018 diving fatalities, injuries, and incidents. Durham (NC): Divers Alert Network; 2021. PMID: 35944087. [cited 2025 Feb 7]. Available from: https://www.dansa.org/annual-diving-report.

3 Berg KM, Bray JE, Ng K, Liley HG, Greif R, Carlson JN, et al. 2023 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations: summary from the basic life support; advanced life support; pediatric life support; neonatal life support; education, implementation, and teams; and first aid task forces. Circulation. 2023;148(24):e187–e280. doi: 10.1161/CIR.0000000000001179. PMID: 37942682. PMCID: PMC10713008.

4 Richardson D, editor. PADI rescue diver manual. Rancho Santa Margarita: International PADI; 2010.

5 Mitchell SJ, Bennett MH, Bird N, Doolette DJ, Hobbs GW, Kay E, et al. Recommendations for rescue of a submerged unresponsive compressed-gas diver. Undersea Hyperb Med. 2012;39:1099–108. PMID: 23342767.

6 Winkler BE, Eff AM, Eff S, Ehrmann U, Koch A, Kähler W, et al. Efficacy of ventilation and ventilation adjuncts during in-water-resuscitation--a randomized cross-over trial. Resuscitation. 2013;84:1137–42. doi: 10.1016/j.resuscitation.2013.02.006. PMID: 23435218.

7 Winkler BE, Muth CM, Kaehler W, Froeba G, Georgieff M, Koch A. Rescue of drowning victims and divers: is mechanical ventilation possible underwater? A pilot study. Diving Hyperb Med. 2013;43:72–7. PMID: 23813460. [cited 2024 Feb 27]. Available from: https://dhmjournal.com/images/IndividArticles/43June/Winkler_dhm.43.2.72-77.pdf.

8 DuCanto J, Lungwitz Y, Koch A, Kahler W, Gessell L, Simanonok J, et al. Mechanical ventilation and resuscitation underwater: Exploring one of the last undiscovered environments - A pilot study. Resuscitation. 2015;93:40–5. doi: 10.1016/j.resuscitation.2015.05.024. PMID: 26051809.

9 Dafilou B, Schwester D, Ruhl N, Marques-Baptista A. It's in the bag: tidal volumes in adult and pediatric bag valve masks. West J Emerg Med. 2020;21:722–6. doi: 10.5811/westjem.2020.3.45788. PMID: 32421525. PMCID: PMC7234703.

10 Devine BJ. Gentamicin therapy. Drug Intell Clin Pharm. 1974;8:650–5.

11 Salyer SW, Steven W. Essential emergency medicine for the healthcare practitioner. Philadelphia (PA): Saunders/Elsevier; 2007. p. 844–913.

12 Gammon RB, Shin MS, Buchalter SE. Pulmonary barotrauma in mechanical ventilation. Patterns and risk factors. Chest. 1992;102:568–72. doi: 10.1378/chest.102.2.568. PMID: 1643949.

13 Russi EW. Diving and the risk of barotrauma. Thorax. 1998;53(Suppl 2):S20–4. doi: 10.1136/thx.53.2008.s20. PMID: 10193343. PMCID: PMC1765901.

14 van Waart H, Harris RJ, Gant N, Vrijdag XC, Challen CJ, Lawthaweesawat C, et al. Deep anaesthesia: The Thailand cave

rescue and its implications for management of the unconscious diver underwater. Diving Hyperb Med. 2020;50:121–9. doi: 10.28920/dhm50.2.121-129. PMID: 32557413. PMCID: PMC7481118.

15 Guardian full face mask owner's manual. Ocean Technology Systems, California, USA; 2014. [cited 2024 Feb 27]. Available from: https://www.oceantechnologysystems.com/wp-content/uploads/2018/06/Guardian-FFM-F.pdf.

16 Winkler BE, Froeba G, Koch A, Kaehler W, Muth CM. Oxylator and SCUBA dive regulators: useful utilities for in-water resuscitation. Emergency Medicine Journal. 2013;30:579–82. doi: 10.1136/emermed-2011-201067.

Acknowledgements

We thank PADI for the development of the rescue diver class and curriculum, which sparked the initial idea for this investigation. We thank representatives from OTS and Neptune who provided detailed information about the relief and exhaust systems of their products to support interpretation of these results.

Conflicts of interest and funding: nil

Submitted: 1 March 2025
Accepted after revision: 7 November 2025
