



# A Novel Application of the N-95 Mask In Times of Critical Shortage

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## Abstract

### Objective

There is still a world-wide N-95 mask shortage in developing countries. Disposable filtering face piece respirators including N95 respirator and surgical masks are designed for one-time use. In view of the increased demand and shortage of supply, even with donations, stocks remain insufficient. When the shortage is critical a means is needed to dramatically increase the supply of these vital masks.

### Methods

A novel application was developed that involves halving the mask, fitting it from the chin-lip crease to the nose tip and affixing it with foam tape.

### Results

Breathability and fit testing confirmed this application to be effective when compared to the standard N-95 respirator. Fortuitously, the mask can be more breathable because of the significant reduction in dead space. Because it is a tape dependent mask, its best use appears to be in the operating room where repeated removal is not done.

### Conclusion

If the supply of N-95 masks for developing countries persists or gets to be serious enough that the gold standard N-95 is wanting, the newly designed half N-95 can provide a viable alternative in difficult times.

**Keywords:** N95; Covid-19; Pandemic; Mask; Respirator

## Introduction

The Covid-19 Pandemic is officially over but there is still a shortage of medical supplies, particularly N-95 masks in developing countries even at this time [1]. They have always struggled with a deficient supply of Personal Protective Equipment. Accordingly,

healthcare workers are wearing these masks for an extended period of time or they consider reusing them to that end we looked at the possibilities of making two effective masks from one by literally cutting the mask in half. The initial intent was to use the two half

masks as a respirator for the nose only. That type of mask for the nose only has been referred to as a quarter mask and has been used under exceptional circumstances [2]. Fortunately, the first author noticed that the half mask itself coincidentally can cover both the nose and mouth but just barely. Although skeptical that this new design would be effective it seemed worthwhile to pursue an investigation for its possible use. That would require finding a way to provide an adequate seal and then performing the appropriate testing methods for effectiveness and usability. Fortunately, prior studies [3] have indicated that tape at the perimeter of the small mask might allow it to only be adherent to the face yet provide a necessary seal.

## Methods

### Mask design modification to create a 'half-mask'

The standard approved N-95 respirator mask (3M 1860 NIOSH N95) is a spheroidal in shape with an elastic band in the upper and lower hemispheres. It has a horizontal crease at the equator coincidentally that allows for an easy bisection into two halves that are almost equal in size. Only one of the two halves has the metallic nasal clip which is left in place. As a result of the mask bifurcation there is fortunately an elastic strap on each of the two halves (Figure 1).



**Figure 1:** The N-95 coincidentally has a horizontal crease at the equator that allows for an easy bisection into two halves that are almost equal in size.

## Protocol

Participants were asked to wear each type of mask (half and full) for a 2hour period while they performed their normal duties (office work). They were instructed on how to apply the half mask to their face. The time of application was confined to the afternoon. The order of mask application was randomized. Testing for leaking was done immediately after mask application. Following each 2hour mask wearing, a breathability test was performed.

## Participants

Participants were 7 (4 male, 3 female) ages 13-50. They were volunteers from the same work environment as that of the senior author. The nature of the experiment was explained and no remuneration was provided. They realized that they were willing volunteers for a medical experiment that had no significant adverse effects. They were instructed that they could remove the mask at any time if they so choose.

## Half-Mask application

Application is the key to success. The mask equator is applied just above the tip of the nose. The uncut curved part of the mask is set into the labiomental crease, i.e., the junction of the lower lip with the chin (Figure 2a). A piece of 1" foam tape is applied to the upper end and seals the mask to the nose. It is important that the upper tape is laid into the concave region between the lateral nose and the cheek – the mentolabial groove. That is a region where all masks have a tendency to leak because of the severe concavity. A lower tape is applied to the lower end of the mask against the chin (Figure 2b) to obtain a proper seal. It should be noted that a wide variety of tapes were tried during a pilot study. Paper tape, anesthesia pink tape, masking tape, Scotch tape and even Duct tape were tried. Foam tape turned out to be the best solution. A Bitrex fit testing kit [4] was used for the half mask and full mask applications to be sure there was a good fit and no leaks (Figure 3). At the completion of each 2-hour mask wearing session, the seal of the tape with the face was confirmed (Figure 2a and 2b).



**Figure 2:**

- a) The half mask extends from the tip of nose to the mentolabia groove.
- b) Foam tape is applied to the nose and chin. But, tape must be applied carefully into the deep concavity between the nose and cheek.



**Figure 3:** Fit test chamber to see if seal of mask is satisfactory.

## Breathability Testing

The two-hour time period for mask wearing was chosen because one study [5] indicated that the mean time for surgery for a wide variety of operations is 130.45 minutes. Since surgery involves less overall bodily mobility than most activities, participants were tested in a slightly more active situation—an office workplace setting. Breathability was assessed with a Likert scale: 1—not very breathable; 5—very breathable. Subsequently, the dead space of both types of masks was measured with rice in order to obtain a percentage of dead space reduction. Since [6] determined that dead space of masks can be accurately determined with a granular material it was done using a large granular material—rice (Figure 3).

## Results

### Mask tolerance

Breathability results indicated better breathing with the half mask. There was a mean score of 2.7 (range of 2-4) for the half

mask compared to 3.8 (range of 3-5) for the full mask using the Likert scoring system. All 7 participants found the breathability to be better with the half mask making it easy to perform a non-parametric statistical test designed for small numbers. It was the Cochran-Q test which revealed  $p < 0.05$ . However, ease of application was better with the full mask in all cases. In contradistinction to the ease of breathability most participants did think it was more effort to apply tape. Some participants did not care for the cosmetic appearance of the half N-95 because of the tape (Table 1). Fit test results indicated that there was no difficulty getting a good fit but only after proper instruction was given for the application of the foam tape particularly in the upper half of the mask. The tape needed to intentionally dip into the concavity that exists between the nose and the cheek. A few fit tests indicated leaks in that region when the participant was not aware that the tape needed to be applied in that location. Once the participant learned the technique of proper taping the issue of proper sealing subsided.

Dead space measurements were as follows. The half N-95 masks exhibited a 50% reduction in dead space compared to the full N-95 masks. Specifically, mean scores for dead space were 72 ml (69-77 range) for the half N-95 compared to 148 ml (144-153 range) for the full N-95. The results are significant at  $p < 0.05$  using the Cochran-Q test (Table 2).

**Table 1:** Breathability scores (n=7) Likert scale: 1- not very breathable; 5 – very breathable.

Participant	Half N95	Full N95
1	3	4
2	2	3
3	2	3
4	3	4
5	4	5
6	2	4
7	3	4
Mean	2.7 (range 2-4)	3.8 (range 3-5)

**Table 2:** Dead Space Rice Test.

Participant	Half mask	Full mask
1	80	170
2	62	150
3	66	135
4	54	139
5	88	145
6	90	135
7	64	162
Mean	72ml (range 54-90)	148ml (range 135-170)

## Discussion

The results suggest that the half N-95 mask is a potentially useful tool in the event of circumstances when there is a desperate shortage. Although it requires foam tape and the tape itself has a few issues, the fact remains that this redesigned mask may be of use in places like the operating room. The better breathability should not be surprising in retrospect when one considers the reduction in dead space provided by the half mask. Dead space is that air which does not participate in gas exchange, is higher in CO<sub>2</sub>, and prompts increased work of breathing. It has prompted the design of masks with exhalation valves to allow CO<sub>2</sub> removal [7]. In that sense, the half mask design not only provides more masks but clearly acts as an effective respirator. That the measured dead space is reduced to approximately one half is no surprise since the mask was literally cut into two parts of almost equal spherical surfaces. That the mask was easily tolerated for 2 hours which is the approximate duration of surgical operations, it would seem to have a useful life time.

In truth it cannot be said that the half N-95 is a better mask than the full mask because it requires some effort to apply it to the face. More important, the half mask cannot be taken on and off the face multiple times without losing its ability to adhere properly to the face. Also, there are some other potential disadvantages to the half mask. One is the need for tape which is a potential acquisition problem for developing countries. Also, the extra effort to have

to apply the tape may be a discouraging factor. Some users might opt to apply it improperly or not apply it at all which would make the mask less effective. The possibility of tape allergy is there but fortunately foam tape is one of the most tolerated tapes by the skin [8]. One of the shortcomings of this study is the subjectivity of the breathability scores. There was no way to conceal the fact that the investigators were interested in finding a new mask that might be superior in one way or another to the traditional N-95. Some of the participants might have been exaggerating their breathability experience in order to appease the investigators. In the final analysis, it is important for the medical institutions anywhere, but particularly those in developing countries where mask shortage continues to be a problem, to have an option of literally doubling their N-95 mask supplies should there be a severe shortage of masks.

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