Irradiation of N95 Masks for their Sterilization and Reuse During the COVID19 Pandemic

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Research Objective

We sought to investigate the feasibility of irradiation for N95 mask sterilization.

Motivation

In the face of the covid19 pandemic, the availability and safety of personal protective equipment (PPE) has been an important topic of discussion. It is essential in keeping our patients as well as our staff safe so that we may continue to provide a high level of care. As healthcare providers around the world began reporting a shortage of PPE, a question resonated throughout the medical research community, what is the best way to sterilize an N95 mask to allow for its safe reuse?

Methodology

Research Questions

- Is a medical linear accelerator capable of delivering the doses needed to inactivate COVID-19?
- Is irradiation with medical linear accelerators an efficient sterilization method?
- Is the functionality of an N95 mask retained after receiving high level doses of ionizing radiation?

Planning

To determine the radiation dose required to inactivate COVID-19, we looked into previous studies of similar viruses. A study published in 2017 by *Kumar et al.* states "1 Mrad was sufficient to reduce titers by 4–5 $\log_{10}$ and that 2 Mrad was sufficient to completely inactivate the virus as determined by plaque assay". 1 Mrad equates to 10 kGy. The dose levels chosen based on this data were **5 kGy, 10kGy, 15 kGy, and 20 kGy.**

Simulation (Figure 1)

- A CT scan of 4 N95 masks was taken. The masks were contoured and the treatment planning system was used to calculate the MU needed to deliver these dose levels.
- An Antero-posterior field was planned to encompass all four masks with two different modalities
  - 6FFF (A 6MV photon beam with no flattening filter which allows for a high dose rate- 2.3x the standard clinical dose rate.)
  - TSET (A 6 MeV electron beam with a very high dose rate- 4x the standard clinical dose rate.)

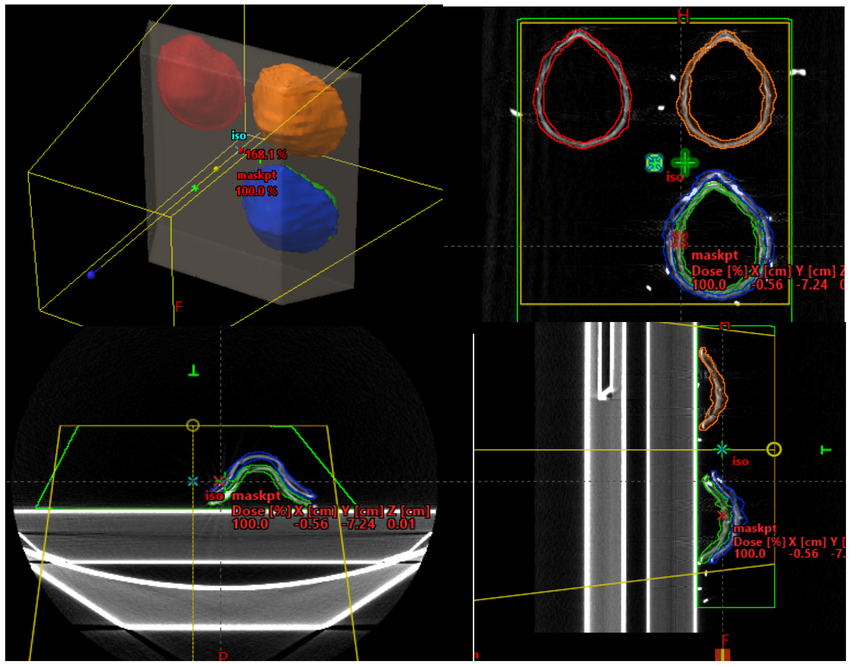

Table 1: Clinical Delivery Setup Variation

Method	Energy	Bolus (mm)	SSD (cm)	Field size	Dose rate (MU/min)	Average cGy/ MU
6FFF (no bolus)	6 MV	0	100	20 cm x 20 cm	1400	0.57
6FFF (3mm)	6 MV	3	100	20 cm x 20 cm	1400	0.85
6FFF (5mm)	6 MV	5	100	20 cm x 20 cm	1400	0.895
TSET (100)	6 MeV	0	100	40 cm x 40 cm	2500	0.73
TSET (90)	6 MeV	0	90	40 cm x 40 cm	2500	0.95
TSET (69)	6 MeV	0	69	40 cm x 40 cm	2500	2.15

Table 2: Delivery Time Estimation

Dose (cGy)	TSET (69)	TSET (90)	TSET (100)	6FFF (5mm)	6FFF (3mm)	6FFF (no bolus)
500000	1.55	3.51	4.57	6.65	7.00	10.44
1000000	3.10	7.02	9.13	13.30	14.01	20.89
1500000	4.65	10.53	13.70	19.95	21.01	31.33
2000000	6.20	14.04	18.26	26.60	28.01	41.77

Delivery

- The linear accelerator ran the beam for approximately 2.5 hour increments daily to achieve the dose levels indicated.
- A number of setups and modalities were investigated (listed in Table 1) to determine the most efficient way to deposit dose with the goal of irradiating multiple masks at a time.
- Measurements were taken with Optically stimulated luminescent detectors (OSLs) to established the dose in cGy per monitor unit (MU) that was delivered to the masks.
- Each mask was irradiated do a specific dose level using a combination of modalities
  - Sample A received 15 kGy in 7.6 hours
  - Sample B received 20 kGy in 10 hours
  - Sample C received 5 kGy in 3.5 hours
  - Sample D received 10 kGy in 7.44 hours
- Samples C and D were sent to the manufacturer to assess the functionality.

Results

- The linear accelerator was able to run nonstop for at least 2.5 hours with no problems. Longer delivery times were not investigated for this portion of the research.
- The TSET delivery method with the smallest SSD was the fastest was to deposit dose. However the field size is reduced at small SSD, reducing the number of masks that can be simultaneously irradiated compared to larger SSD setups.

3M performed the NIOSH N95 certification test on samples C and D. The performance of each of these samples is seen below.

- Sample C which received 5 kGy showed 45% NaCl aerosol penetration or 55% filtration efficiency.
- Sample D which received 10 kGy showed 51.2% NaCl aerosol penetration or 48.8% filtration efficiency.

The penetration of NaCl aerosol through a typical 3M 1860 respirator is between 0.1% and 0.6% or 99.9 to 99.4% filtration efficiency

Conclusion

The results of these tests indicate that N95 masks do not retain their functionality when exposed to high levels of ionizing radiation. The material responsible for filtration performance was degraded far beyond a clinically acceptable level. Therefore, irradiation is not an acceptable method of sterilization for the reuse of N95 masks.

Kumar, M., Mazur, S., Ork, B. L., Postnikova, E., Hensley, L. E., Jahrling, P. B., Johnson, R., & Holbrook, M. R. (2015). Inactivation and safety testing of Middle East Respiratory Syndrome Coronavirus. *Journal of virological methods*, *223*, 13–18. https://doi.org/10.1016/j.jviromet.2015.07.002

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