Online Data Supplement

# Aerosol Generation from the Respiratory Tract with Various Modes of Oxygen Delivery

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Supplementary Methods:

*Procedures:*

The study was conducted over 2 consecutive days in one of our pulmonary function laboratory rooms. The entire pulmonary function laboratory is negative pressure, and the particular room we used has 15 air exchanges per hour. We utilized a recirculating air scrubber with a HEPA filter that operated continuously throughout the day. These room conditions were needed in order to decrease the measured background particles and improve the signal-to-noise ratio. The room thermostat was set at 71 degrees Fahrenheit, but we did not measure the actual room temperature throughout the study. The room humidity was not able to be controlled, and was not measured. Air currents in the room were not mapped out.

*Measurements:* Baseline room measurements were taken with the funnel opening directed away from the participant (and the research team) in order to limit any exhaled particles from being measured. Measurements 2 – 5 (the various breathing maneuvers) were taken with the funnel opening directed toward the participant.

*Determination of number and size of respiratory particles:* Our experimental set up was based on work accomplished by Asadi et al (13, 15), which measured particles during speech using the same aerodynamic particle spectrometer (TSI model 3321) with a funnel. In order to accommodate space for oxygen devices, such as the face mask and NIPPV mask to be worn in front of the funnel, we standardized all measurements to be approximately 5 cm from the participant's mouth to the widest circumference of the funnel.

Supplemental Table/Figure Legends:

Table E1: Particle number concentration of oxygen systems alone. Measurements were taken on the 1st day of testing. Each measurement was collected only once. Measurements were similar to the methods during human testing, except no participants were connected to the oxygen systems during these measurements. Oxygen systems were 5 cm away and aimed at the collection funnel. For each oxygen condition (and background room air), 1 second spectra were sampled for 100 seconds. Background room air is higher than the value reported in the main text of 0.060 particles/$cm^3$, because 0.060 particles/$cm^3$ represented the average over the 2 days of study, whereas the value of 0.120 is the median value of a 100 second sample just prior to testing these oxygen modalities. NIPPV was not tested because there was a filter between the machine and tubing, and the machine would alarm and give erratic flows if not connected to an individual. The number of particles from the oxygen systems alone were lower than the background air at the time of testing, but similar to the background air over the course of the 2 days (0.060 particles/$cm^3$). We believe the wall oxygen used in the study to be particle-free, or at least immeasurably low. NC = nasal cannula, FM = face mask, HFNC = heated and humidified high flow nasal cannula. Median (IQR) particle number concentrations are reported in the table. Between group differences assessed with the Kruskal-Wallis test.

Table E2: Comparison of background air of the testing room to breathing with room air and oxygen devices. This is similar to Table 2 in the main text, but values of the background air of the room have been added for comparison. Coughing produces a higher number of particles and droplets than the background room air with the exception of NIPPV. For nearly all test

conditions the measured diameter of particles and droplets is smaller than the background air of the room. All data median (IQR). RA = room air, L/min = liters per minute, NC = nasal cannula, FM = face mask, HFNC = heated and humidified high flow nasal cannula, NIPPV = non-invasive positive pressure ventilation. For each breathing maneuver, pairwise comparisons of the background air to each oxygen delivery modality was made with Wilcoxon matched-pairs signed rank test. P value adjusted for multiple comparisons with the Holm method.

*adjusted $P < 0.05$.

Figure E1: Diagram of the experimental setup. The participant was seated upright in a chair with the funnel sampler directed toward the mouth and at a distance of approximately 5 cm from the mouth to the widest portion of the funnel. The supply of oxygen and oxygen delivery devices were behind the participant (left side of the image). The research team was in front of the participant (right side of the image). 3 members of the research team were present in the room during measurements. Y.P. operated the aerodynamic particle spectrometer. J.L. was responsible for data collection. N.G. verbally instructed the participant on the experimental procedures, changed the oxygen delivery devices, and measured respiratory rate during deep breathing. N.G. also measured the distance from the mouth to the funnel at 5 cm. Y.P and J.L wore surgical masks and remained seated during measurements. N.G. wore an N95 mask and only moved in the room in order to change oxygen delivery mechanisms.

Figure E2: Particle number concentration exhaled over time on a logarithmic scale with the various oxygen modalities and respiratory maneuvers. White colored rectangles denote background room measurements. NC = nasal cannula; FM = face mask; HFNC = heated and

humidified high flow; NIPPV = non-invasive positive pressure ventilation; L/min = liters per minute; N = normal breathing; T = talking; D = deep breathing; C = coughing. P1 – P10 are participants 1 through 10.

Table E1 - Particle number concentration of oxygen systems alone

| | Background Room Air | 4L/min NC | 15 L/min FM | 10 L/min HFNC | 30 L/min HFNC | 50 L/min HFNC | *P* Value |
|---|---|---|---|---|---|---|---|
| Particle Number Concentration (particles/$cm^3$) – Median (IQR) | 0.120 (0.120-0.120) | 0.060 (0.045-0.135) | 0.060 (0.0-0.120) | 0.060 (0.0-0.060) | 0.060 (0.0-0.060) | 0.060 (0.0-0.060) | 0.0207 |

Table E2 –

| | Background Air | RA | 4 L/min NC | 15 L/min FM | HFNC 10 L/min | HFNC 30 L/min | HFNC 50 L/min | NIPPV 12/5 | NIPPV 20/10 |
|---|---|---|---|---|---|---|---|---|---|
| Particle Number Concentration (particles/cm$^3$) – Median (IQR) | | | | | | | | | |
| Normal Breathing | 0.060 (0.035 - 0.077) | 0.068 (0.046 - 0.091) | 0.060 (0.044 - 0.065) | 0.059 (0.055 - 0.074) | 0.050 (0.036 - 0.076) | 0.046 (0.035 - 0.073) | 0.041 (0.025 - 0.056) | 0.056 (0.036 - 0.079) | 0.057 (0.037 - 0.090) |
| Talking | 0.060 (0.035 - 0.077) | 0.071 (0.056 - 0.104) | 0.064 (0.049 - 0.080) | 0.063 (0.050 - 0.074) | 0.074 (0.054 - 0.088) | 0.058 (0.051 - 0.072) | 0.055 (0.037 - 0.069) | 0.049 (0.030 - 0.070) | 0.046 (0.038 - 0.064) |
| Deep Breathing | 0.060 (0.035 - 0.077) | *0.105 (0.080 - 0.115) | 0.087 (0.061 - 0.107) | 0.068 (0.047 - 0.080) | 0.074 (0.052 - 0.110) | 0.067 (0.053 - 0.074) | 0.058 (0.046 - 0.090) | 0.050 (0.037 - 0.091) | 0.044 (0.038 - 0.068) |
| Cough | 0.060 (0.035 - 0.077) | *0.138 (0.098 - 0.191) | *0.168 (0.122 - 0.195) | *0.126 (0.095 - 0.313) | *0.141 (0.133 - 0.188) | 0.099 (0.078 - 0.176) | *0.141 (0.095 - 0.180) | 0.089 (0.055 - 0.098) | 0.063 (0.047 - 0.125) |
| Particle Geometric Mean Diameter (μm) – Median (IQR) | | | | | | | | | |
| Normal Breathing | 1.90 (1.75 - 2.07) | *1.48 (1.22 - 1.54) | *1.58 (1.43 - 1.61) | 1.46 (1.24 -1.86) | *1.42 (1.28 -1.51) | *1.30 (1.12 -1.50) | *1.19 (1.01 -1.56) | 1.45 (1.32 -1.83) | 1.43 (1.21 -1.95) |
| Talking | 1.90 (1.75 -2.07) | *1.28 (1.14 -1.43) | *1.46 (1.20 -1.50) | *1.33 (1.12 -1.64) | *1.26 (1.23 -1.32) | *1.51 (1.32 -1.53) | *1.29 (1.14 -1.50) | *1.44 (1.24 -1.56) | 1.36 (1.20 -1.84) |
| Deep Breathing | 1.90 (1.75 - 2.07) | *1.00 (0.98 -1.14) | *1.16 (1.02 -1.31) | *1.12 (1.00 -1.36) | *1.14 (1.00 -1.33) | *1.19 (0.99 -1.33) | *1.25 (0.92 -1.42) | *1.38 (1.09 -1.50) | 1.53 (1.09 -1.70) |
| Cough | 1.90 (1.75 - 2.07) | *1.03 (0.94 -1.46) | *1.01 (0.93 -1.20) | *1.35 (0.95 -1.45) | *1.09 (1.01 -1.27) | *1.04 (0.93 -1.17) | *0.93 (0.86 -1.09) | *1.18 (1.02 -1.38) | *1.20 (0.88 -1.95) |

Figure E1 –

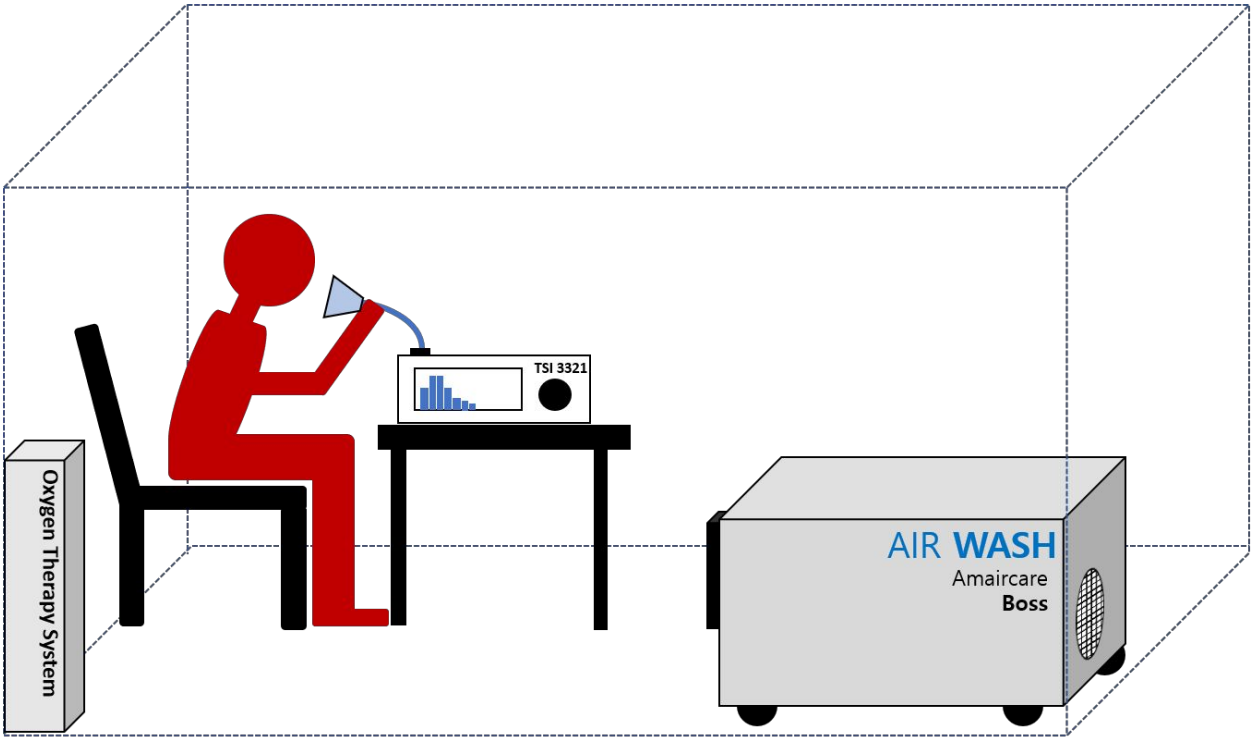
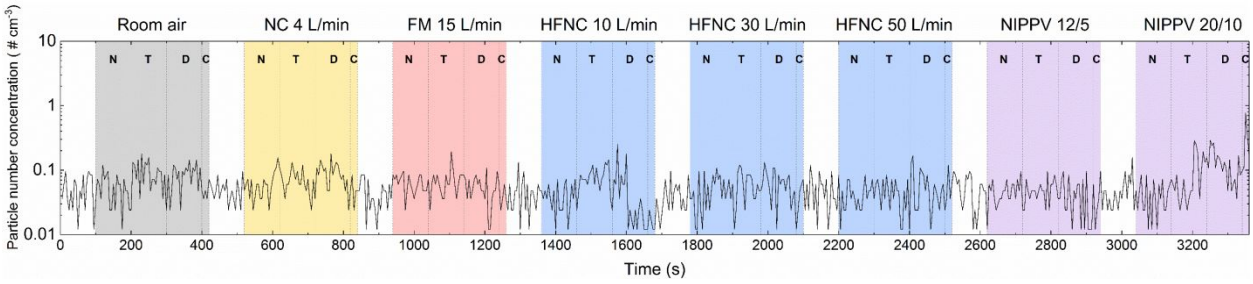


Figure E2 –

P1:

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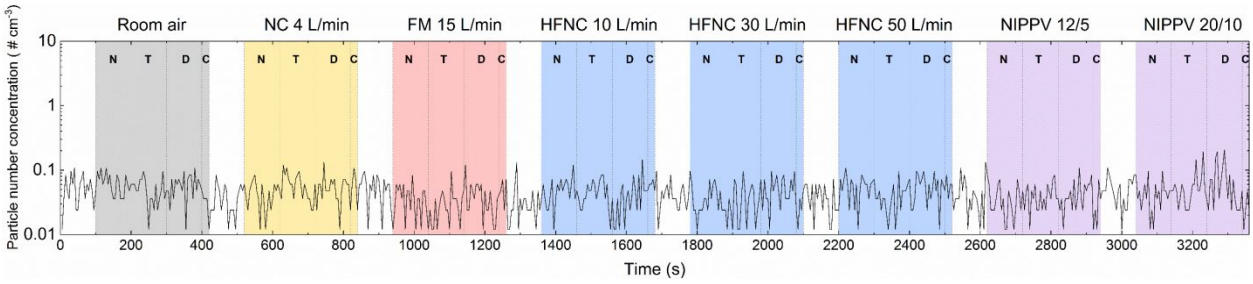


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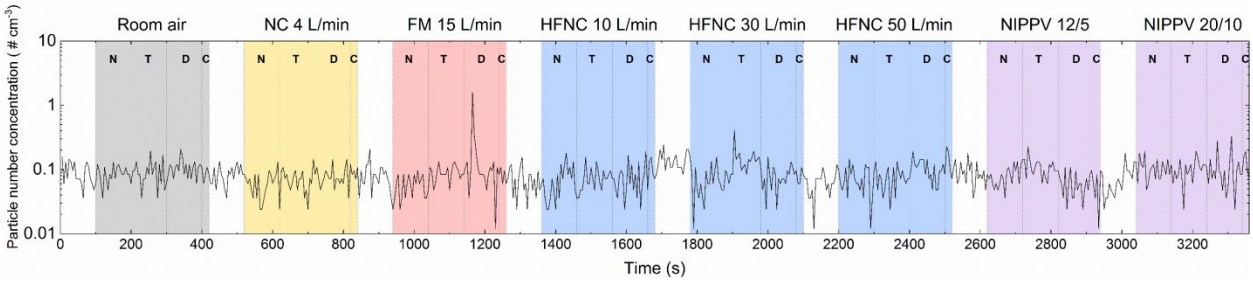


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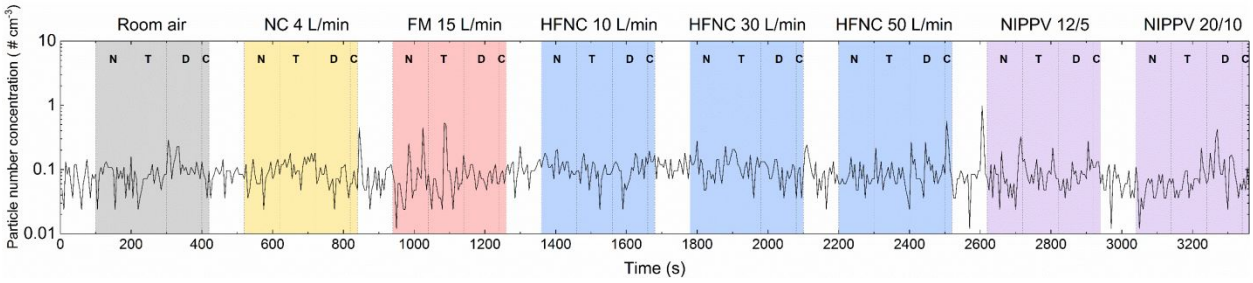

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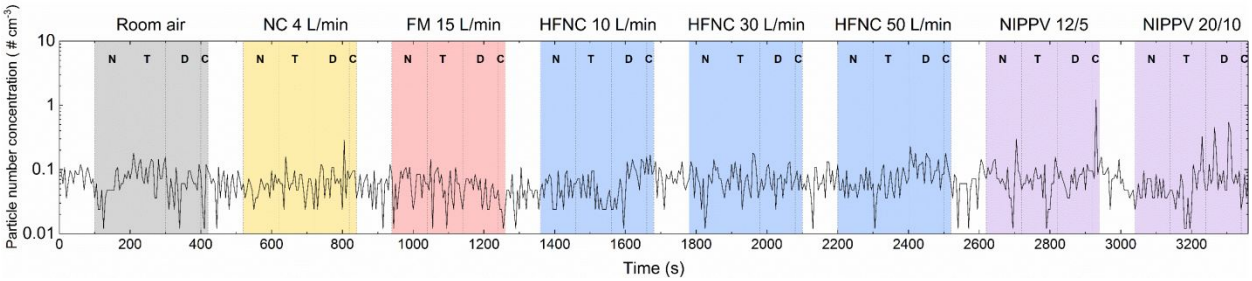
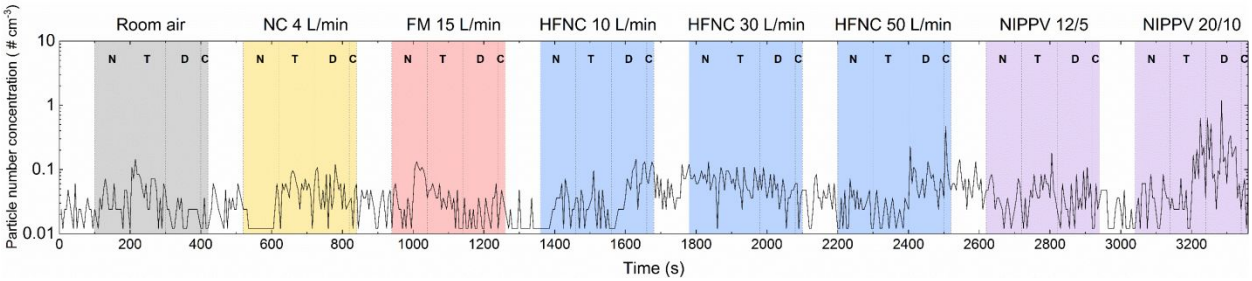
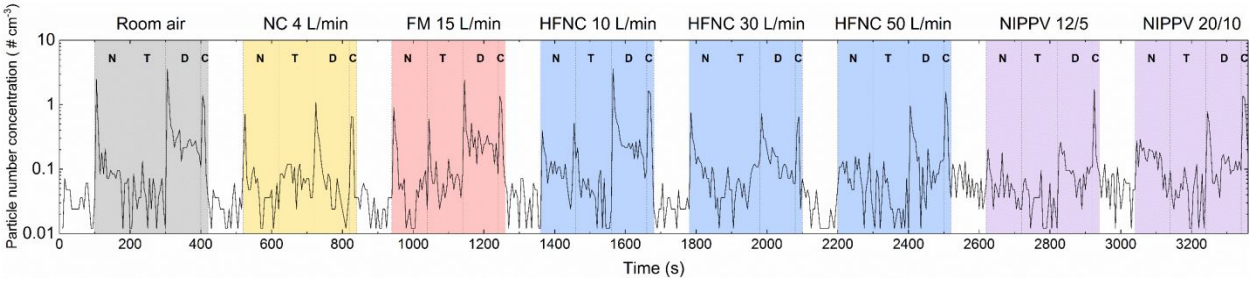

Room air
NC 4 L/min
FM 15 L/min
HFNC 10 L/min
HFNC 30 L/min
HFNC 50 L/min
NIPPV 12/5
NIPPV 20/10
N T D C
Particle number concentration ( # cm-3)
Time (s)

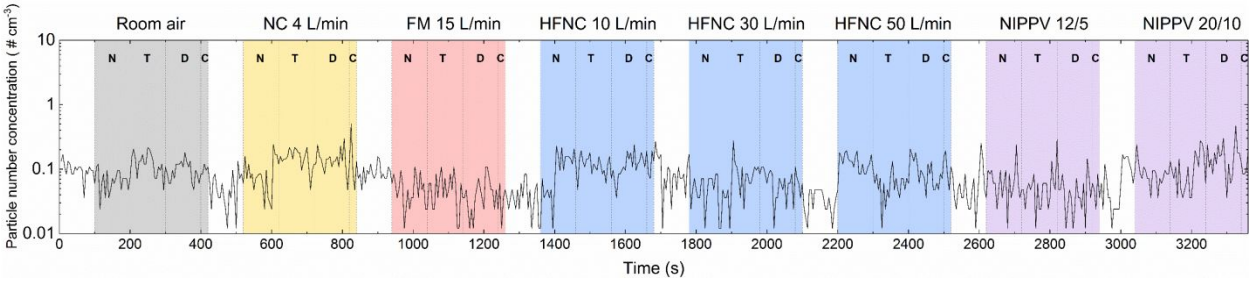
P6:


Room air
NC 4 L/min
FM 15 L/min
HFNC 10 L/min
HFNC 30 L/min
HFNC 50 L/min
NIPPV 12/5
NIPPV 20/10
N T D C
Particle number concentration ( # cm-3)
Time (s)

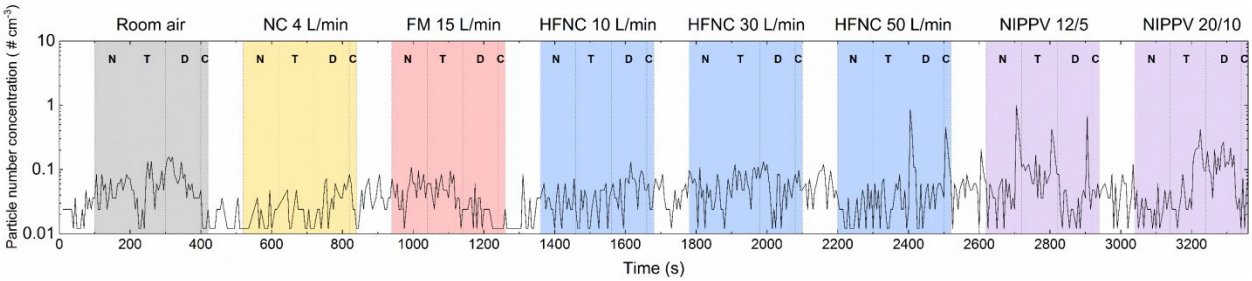
P7:


Room air
NC 4 L/min
FM 15 L/min
HFNC 10 L/min
HFNC 30 L/min
HFNC 50 L/min
NIPPV 12/5
NIPPV 20/10
N T D C
Particle number concentration ( # cm-3)
Time (s)

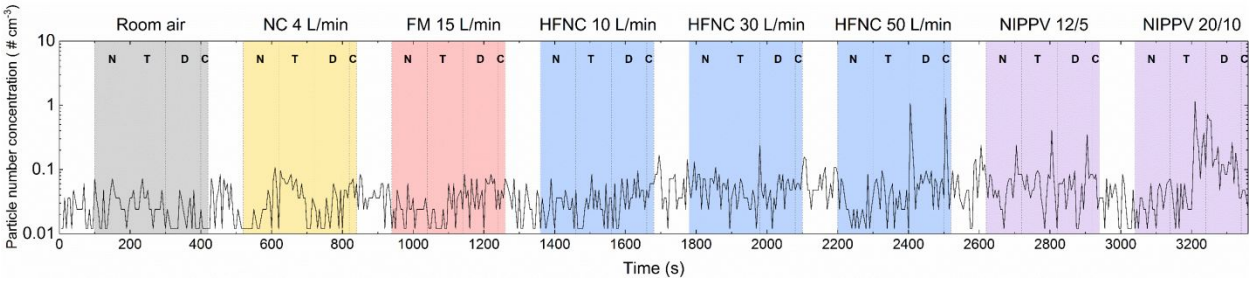
P8:


Room air
NC 4 L/min
FM 15 L/min
HFNC 10 L/min
HFNC 30 L/min
HFNC 50 L/min
NIPPV 12/5
NIPPV 20/10
N T D C
Particle number concentration ( # cm-3)
Time (s)

P9:


Room air
NC 4 L/min
FM 15 L/min
HFNC 10 L/min
HFNC 30 L/min
HFNC 50 L/min
NIPPV 12/5
NIPPV 20/10
N T D C
Particle number concentration ( # cm-3)
10
1
0.1
0.01
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200
Time (s)

P10:


Room air
NC 4 L/min
FM 15 L/min
HFNC 10 L/min
HFNC 30 L/min
HFNC 50 L/min
NIPPV 12/5
NIPPV 20/10
N T D C
Particle number concentration ( # cm-3)
10
1
0.1
0.01
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200
Time (s)