Determining the Effect of Patient Mouth Opening on Non-Invasive Respiratory Therapy Effectiveness

By Robert Kacinski and Wayne Strasser, Ph.D., P.E.

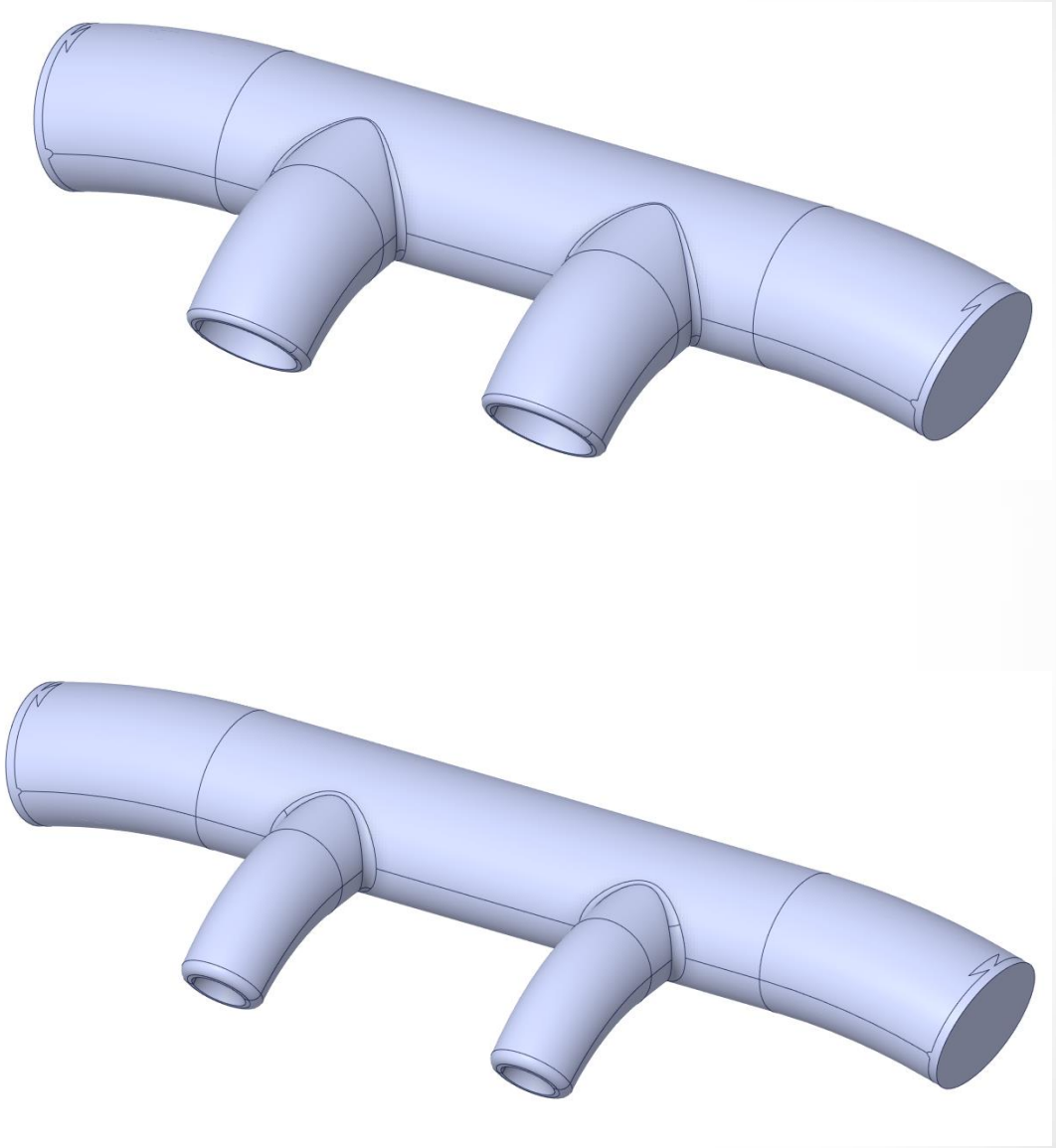
Funding and support provided by Vapotherm Inc. (Exeter, NH)

For more information on our research, visit our webpage at www.fluidgroup.org

LIBERTY UNIVERSITY

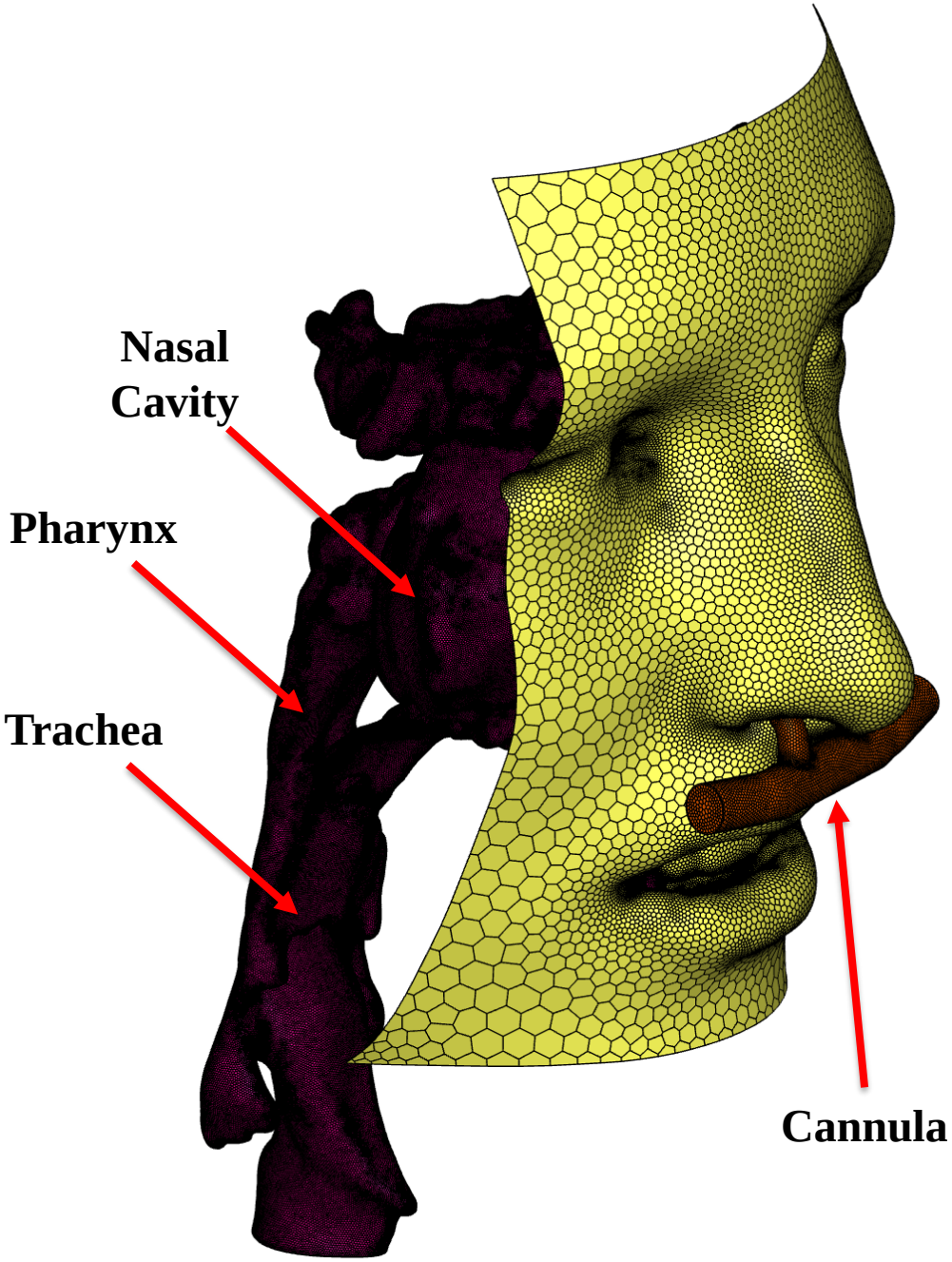
Background

- High Flow Nasal Cannula (HFNC) Oxygen Therapy
  - Non-invasive respiratory therapy delivering heated, humidified oxygen via a nasal cannula
- High Velocity Nasal Insufflation (HVNI)
  - Subset of HFNC oxygen therapy in which the flow is delivered at higher velocities



Fluid Domain

- CT scans were taken of a human airway to be converted to a computational mesh.
- The domain consists of the:
  - Trachea
  - Pharynx
  - Nasal cavity
  - Oral cavity
  - Environment region (not shown) in front of the patient face



Boundary Conditions

Airway "Inlet"

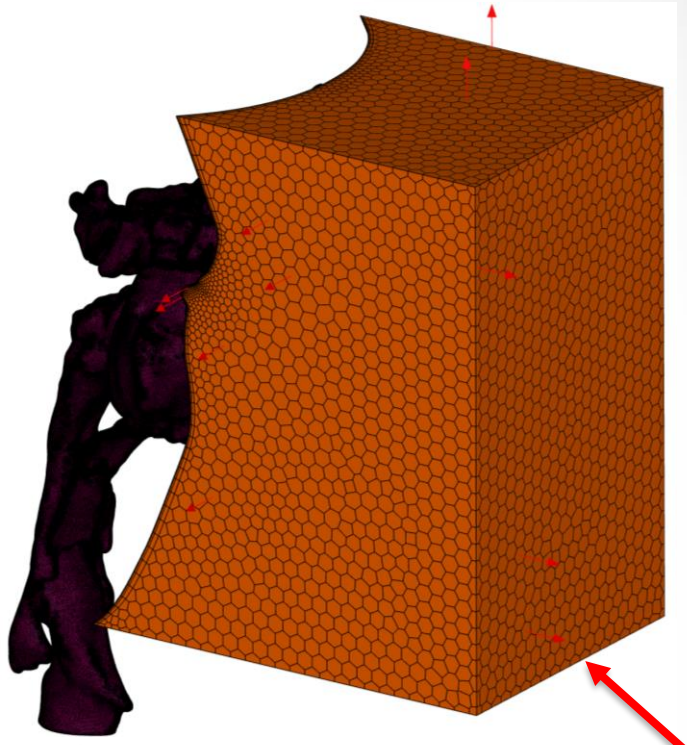
- Temporally varying velocity boundary controlling:
  - Volume flow rate
  - Species concentrations

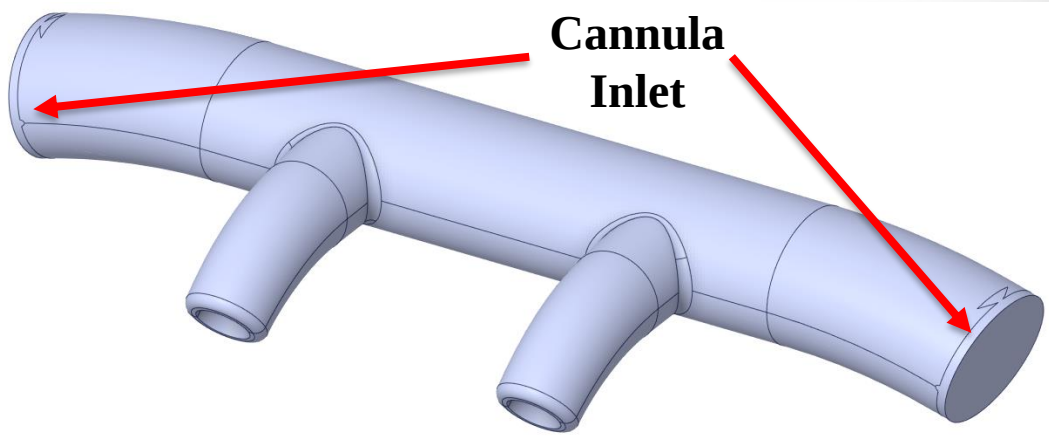
Cannula Inlet

- Steady input of 100% O_2 at 35 liters per minute

Environment Outlet

- Pressure outlet with species feedback of 0.21 mole fraction O_2 (ambient air)



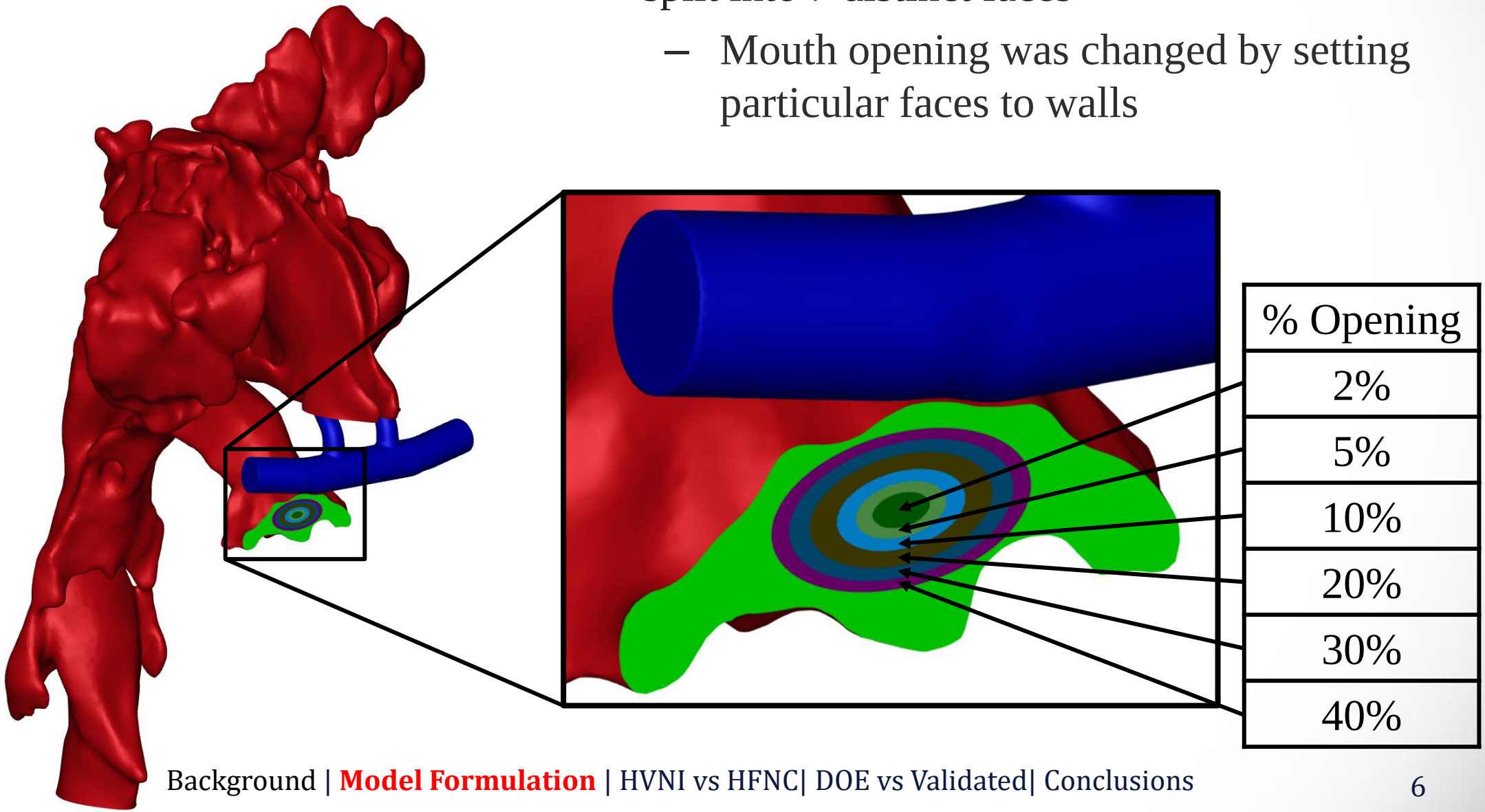


Previous Work

- Prior research has examined the distinction between HFNC and HVNI for open and closed mouth cases
- This study aims to provide a more comprehensive analysis of how mouth opening affects CO_2 flush for HFNC and HVNI therapy

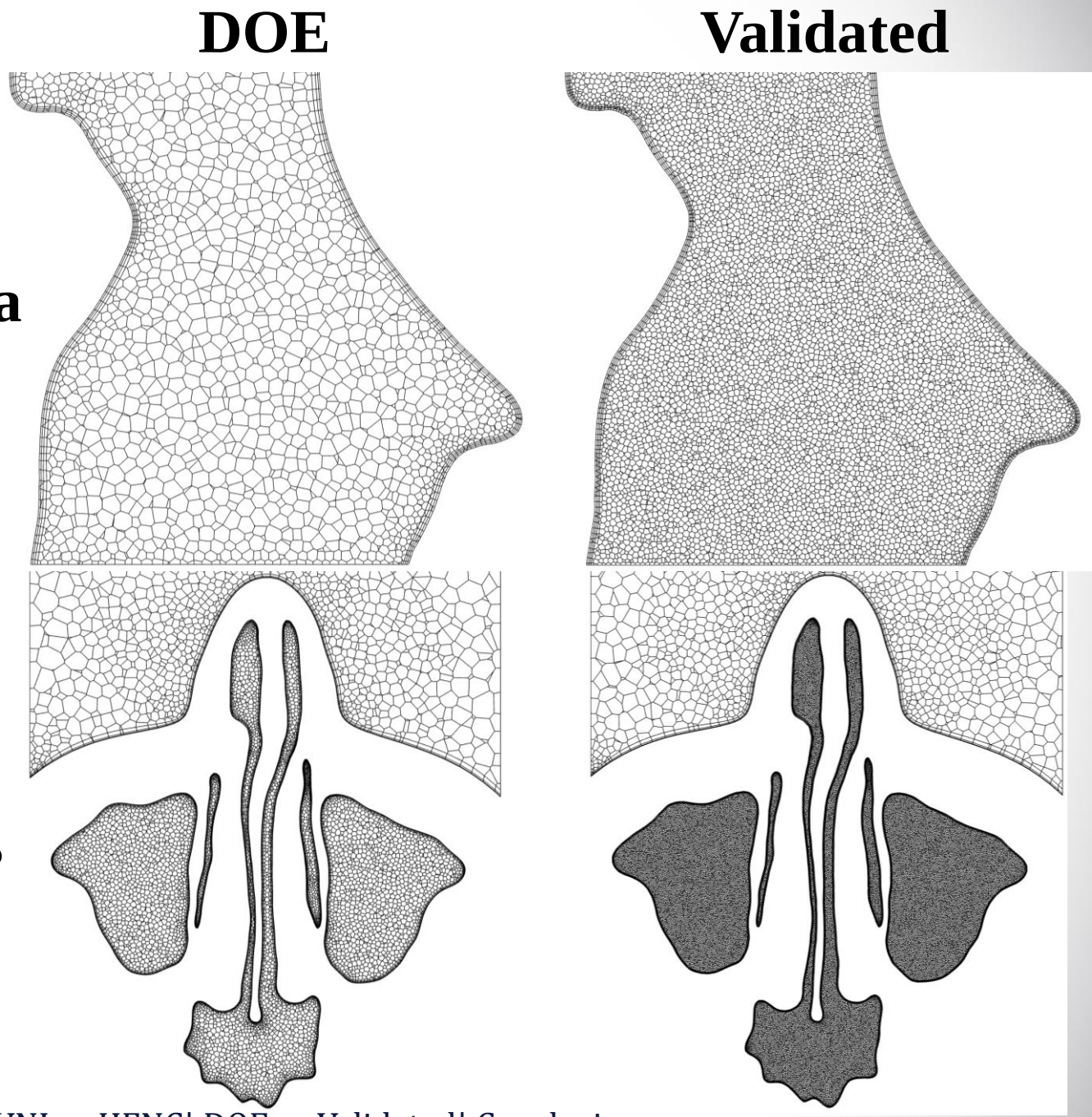
Mouth Openings

- Interface between airway and environment was split into 7 distinct faces
  - Mouth opening was changed by setting particular faces to walls



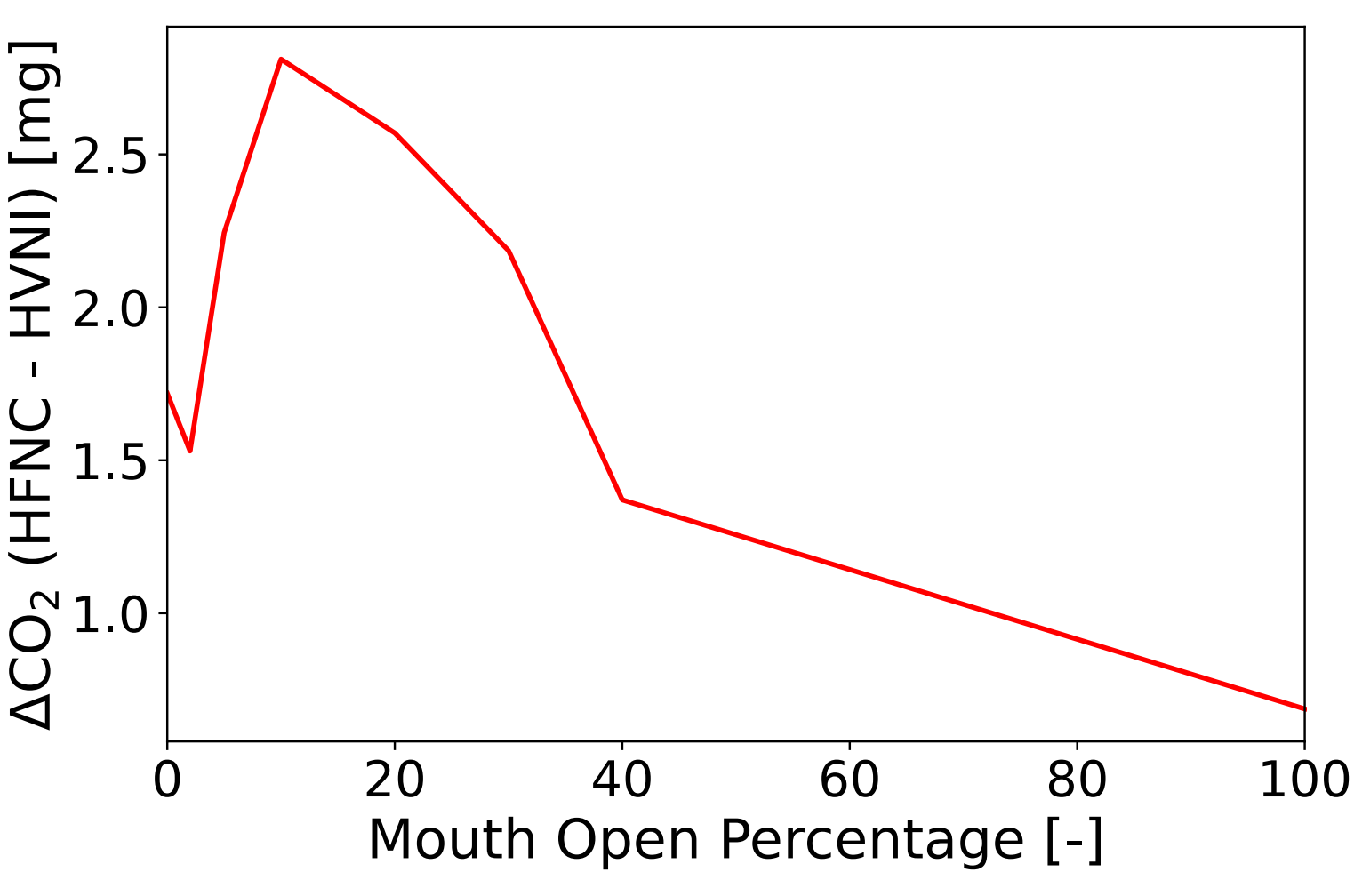
Meshing

- Two mesh densities:
  - Validated
    - ~8 million polyhedral cells
  - DOE
    - ~1/4 cell count of Validated mesh
- DOE mesh used to narrow range of mouth openings to test



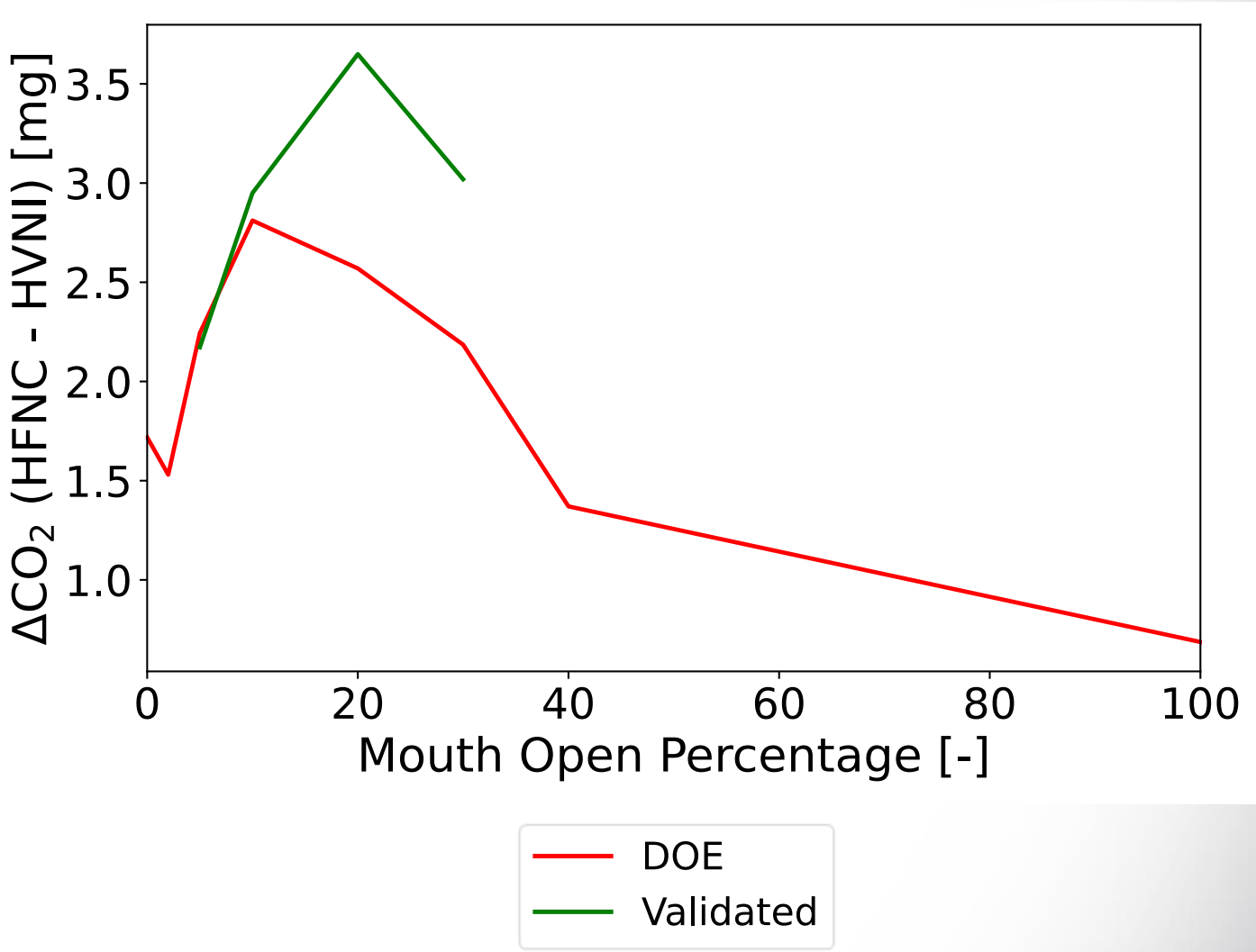
HVNI vs HFNC (DOE)

- 16 DOE models:
  - 2 therapy types
  - 8 mouth openings
- Peak therapy discrepancy at a mouth opening of 10%



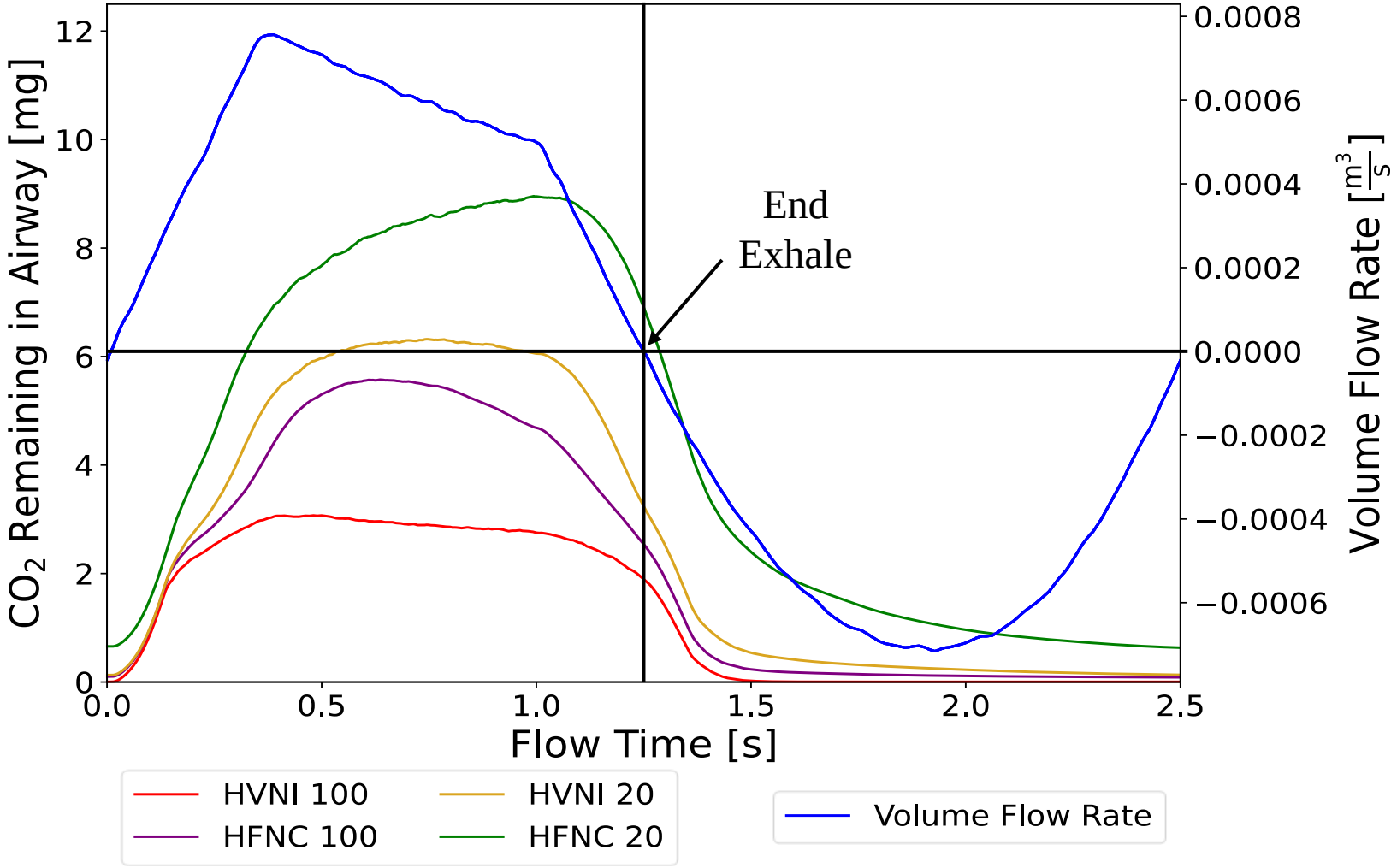
HVNI vs HFNC (DOE + Validated)

- 8 validated models:
  - 2 therapy types
  - 4 mouth openings
- The magnitude and location of the peak discrepancy changed
  - The impact of decreasing mesh density was not predictable



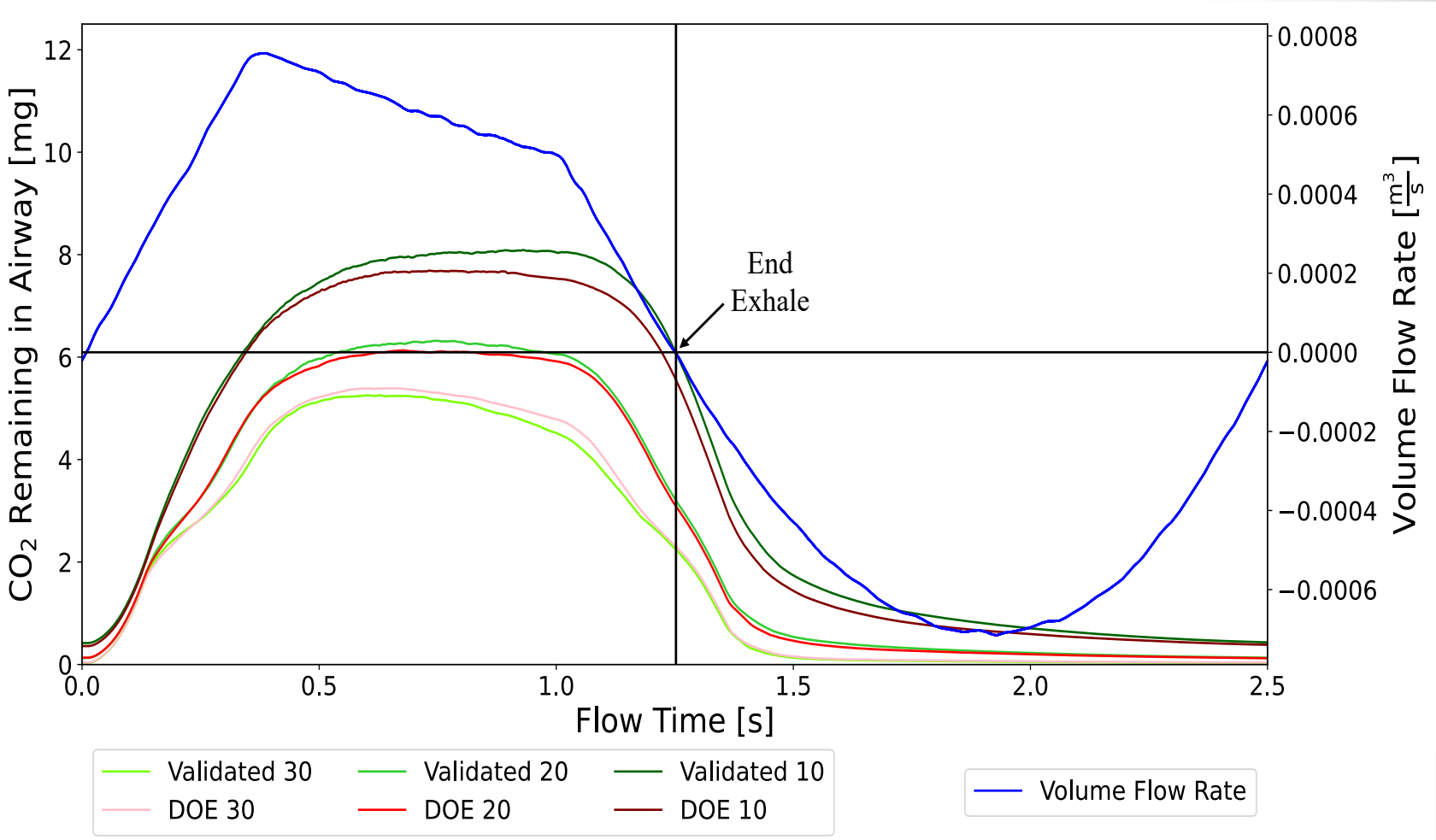
HVNI vs HFNC (Validated)

- Instantaneous CO_2 remaining for a complete breath cycle
- Notice the shape change for each therapy type when moving from 100 percent open to 20 percent open
- HFNC end-exhale CO_2 increases by ~4 mg



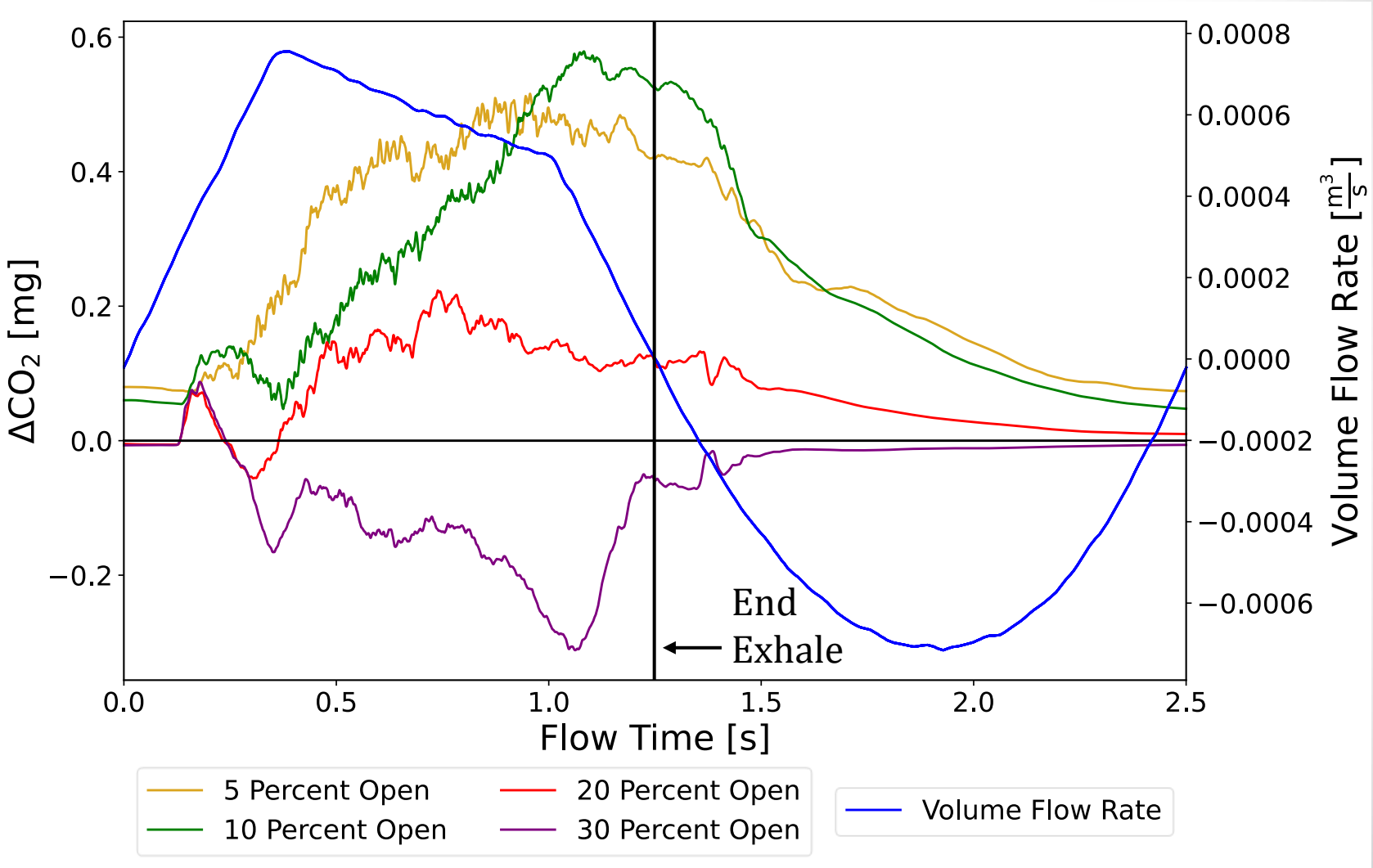
DOE vs Validated 1 (HVNI)

- DOE and Validated models shown for 3 different mouth openings.
  - All models were administered HVNI therapy.
- The discrepancy between the two modeling methodologies can be seen throughout the breath cycle.
- A closer look at the effect of mesh density is to follow.



DOE vs Validated 2 (HVNI)

- Instantaneous effect of mesh density plotted for a complete breath cycle
- ΔCO_2 is now comparing DOE and Validated models
- All models displayed received HVNI therapy
- 30 percent open curve highlights the unpredictable nature of variation due to mesh coarsening



Conclusions

- HVNI outperformed HFNC at all mouth openings, but the magnitude of change between the therapies was a function of mouth opening
  - At a mouth opening of 20%, the models being administered HFNC therapy had ~3.5 mg of additional CO_2 in the airway
  - This additional CO_2 is equivalent to 24% of the airway being filled with stale CO_2 rich expiratory flow
- Coarse models are unpredictable in their variability from validated counterparts
  - However, if used properly, they still can provide useful information

THANK YOU

LIBERTY UNIVERSITY
SCHOOL of ENGINEERING