

SUPPLEMENTARY MATERIAL

Effects of varying inhalation duration and respiratory rate on human airway flow

Manikantam G. Gaddam and Arvind Santhanakrishnan

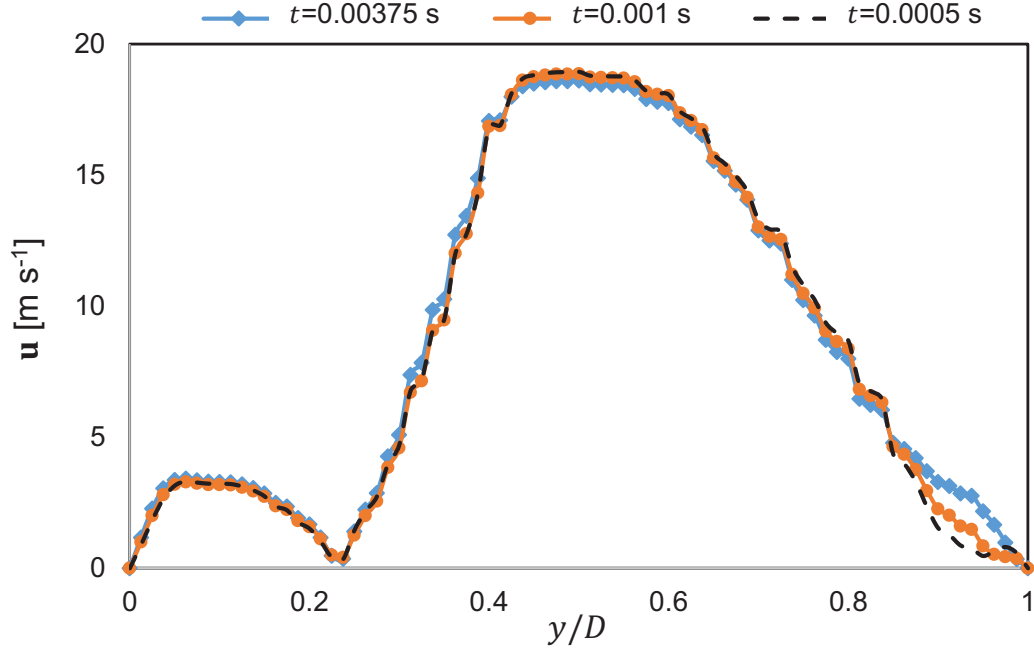


Figure S1. Time-step size independence test for $Wo = 24.1$ and $IT/BT = 50\%$. Three-dimensional velocity (u) was extracted along the coronal plane in the upper trachea (plane 1 in **Table 2**) and plotted as a function of non-dimensional diameter y/D . D = trachea diameter = 18 mm.

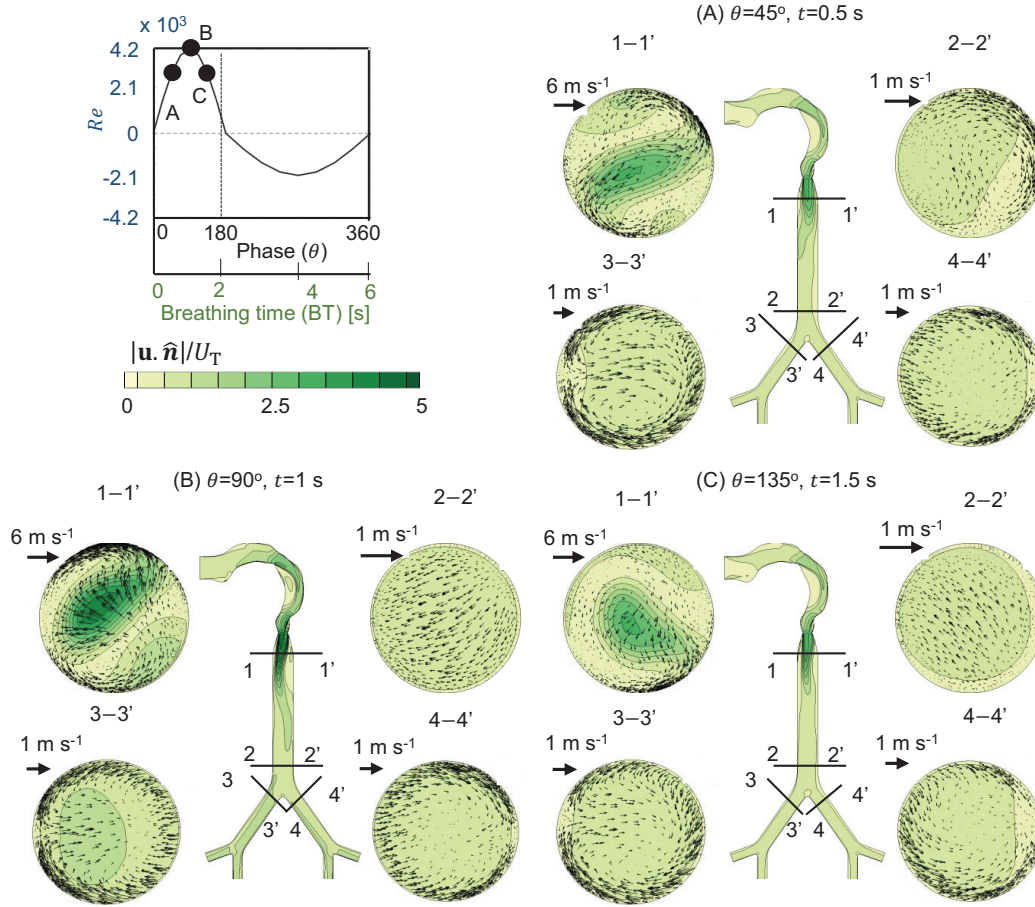


Figure S2. Contours of magnitude of plane-normal velocity component (non-dimensionalized with mean flow speed in trachea, U_T) with superimposed in-plane velocity vectors for planes 1–4 at various time points during inhalation for $Wo = 2.41$ at $IT/BT = 33\%$. A is at phase $\theta = 45^\circ$ ($= 25\%$ IT), B is at phase $\theta = 90^\circ$ ($= 50\%$ IT) and C is at phase $\theta = 135^\circ$ ($= 75\%$ IT). Coronal plane shows the locations of each plane.

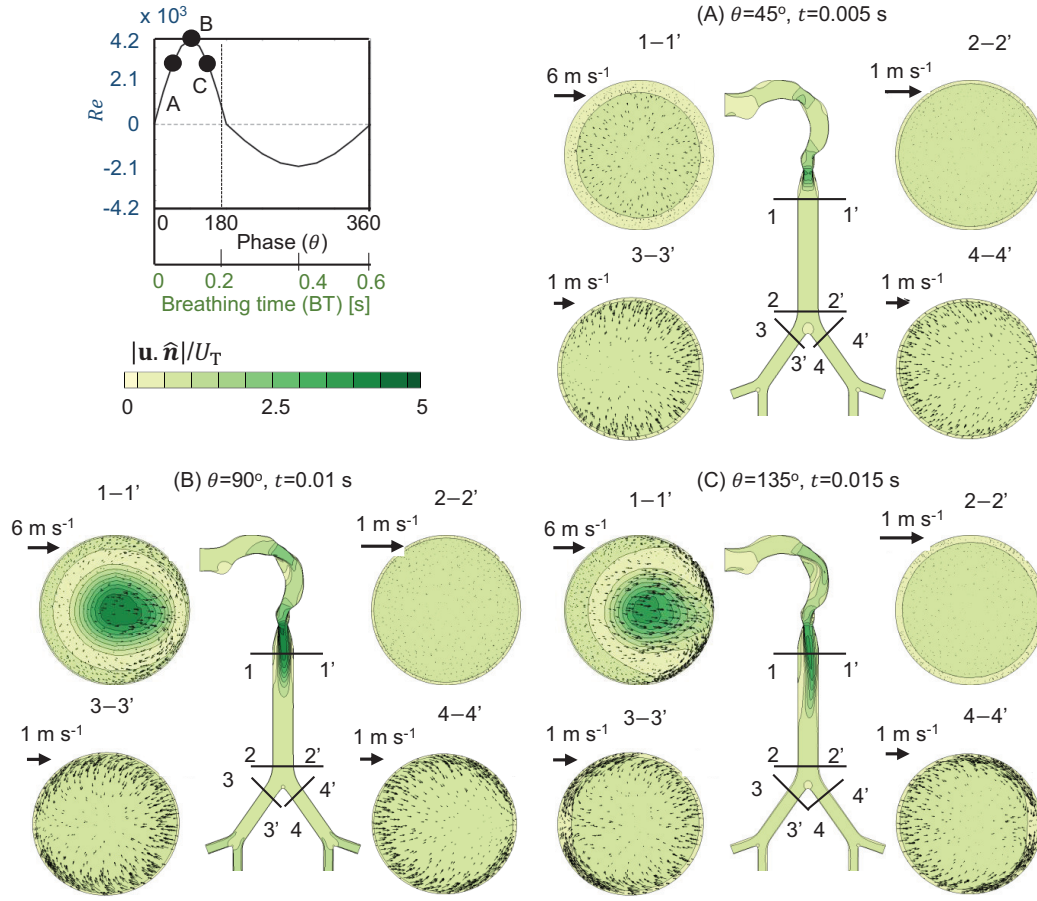


Figure S3. Contours of magnitude of plane-normal velocity component (non-dimensionalized with mean flow speed in trachea, U_T) with superimposed in-plane velocity vectors for planes 1–4 at various time points during inhalation for $Wo = 24.1$ at $IT/BT = 33\%$. A is at phase $\theta = 45^\circ$ ($=25\%$ IT), B is at phase $\theta = 90^\circ$ ($=50\%$ IT) and C is at phase $\theta = 135^\circ$ ($=75\%$ IT).

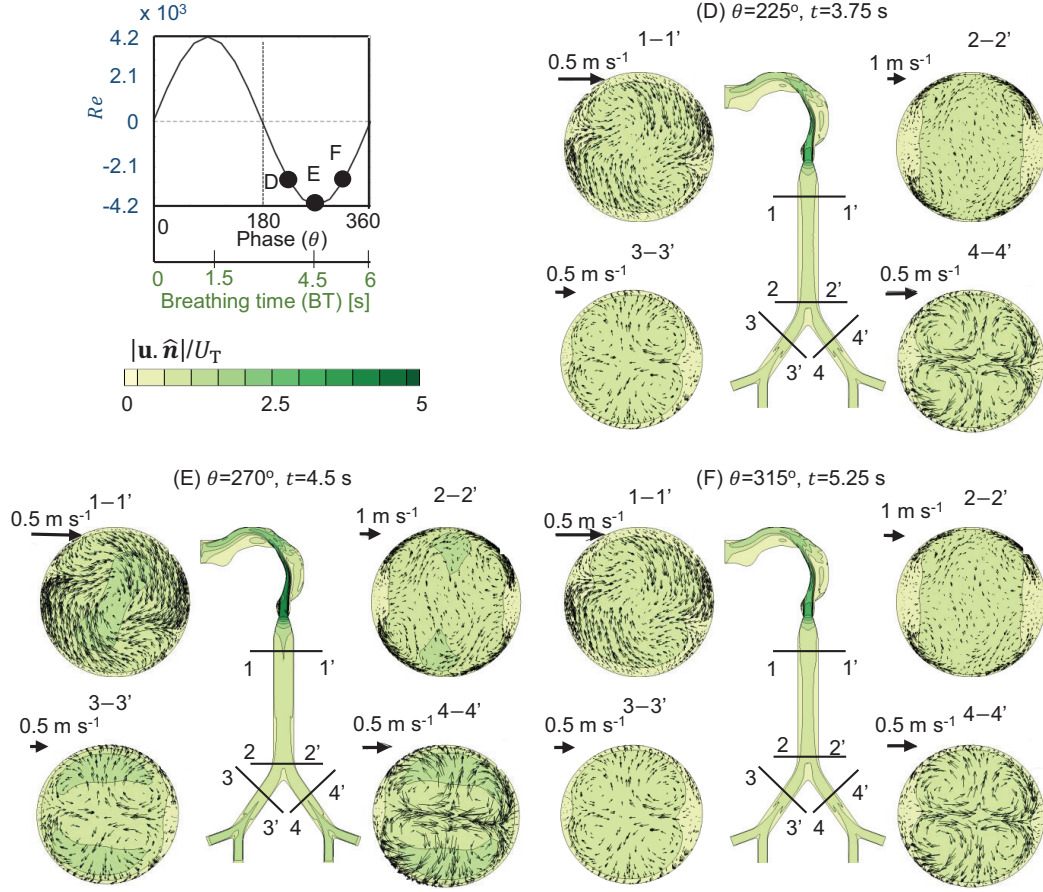


Figure S4. Contours of magnitude of plane-normal velocity component (non-dimensionalized with mean flow speed in trachea, U_T) with superimposed in-plane velocity vectors for planes 1–2 at various time points during exhalation for $Wo = 2.41$ at IT/BT = 50%. D is at phase $\theta = 225^\circ$ (= 25% ET), E is at phase $\theta = 270^\circ$ (= 50% ET) and F is at phase $\theta = 315^\circ$ (= 75% ET).

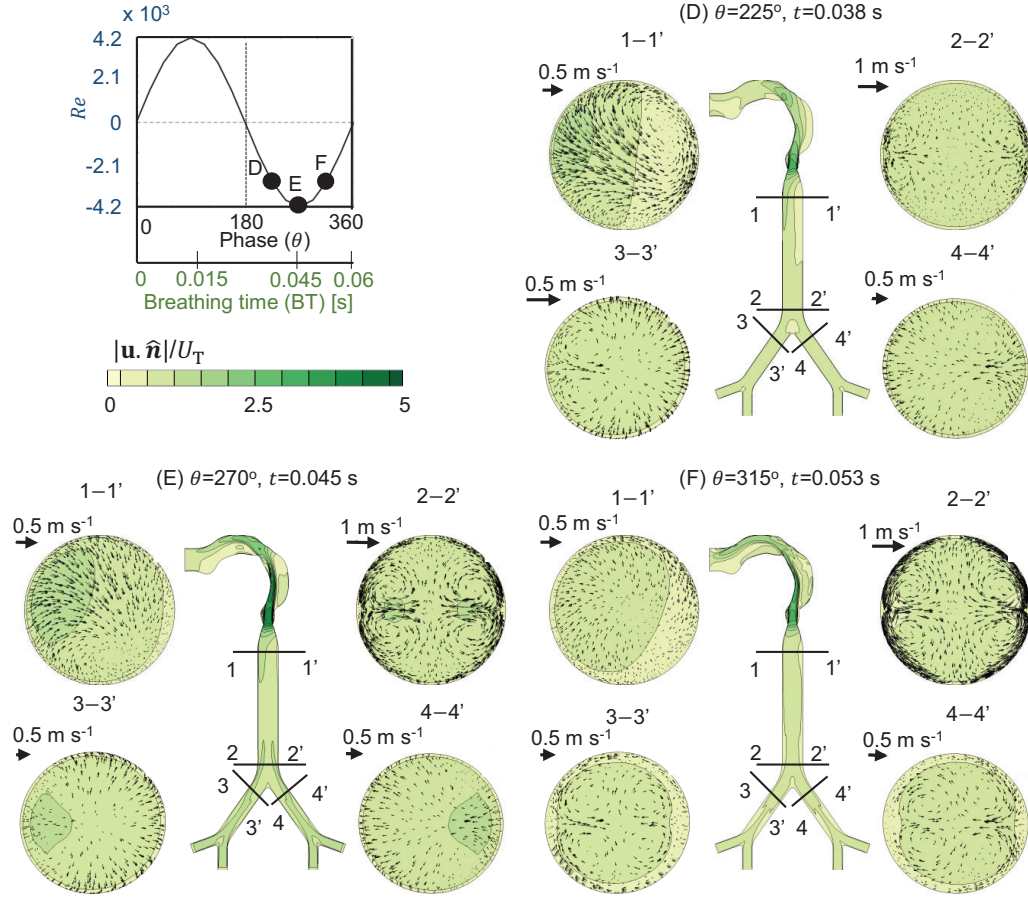


Figure S5. Contours of magnitude of plane-normal velocity component (non-dimensionalized with mean flow speed in trachea, U_T) with superimposed in-plane velocity vectors for planes 1–2 at various time points during exhalation for $Wo = 24.1$ at IT/BT = 50%. D is at phase $\theta = 225^\circ$ (= 25% ET), E is at phase $\theta = 270^\circ$ (= 50% ET) and F is at phase $\theta = 315^\circ$ (= 75% ET).

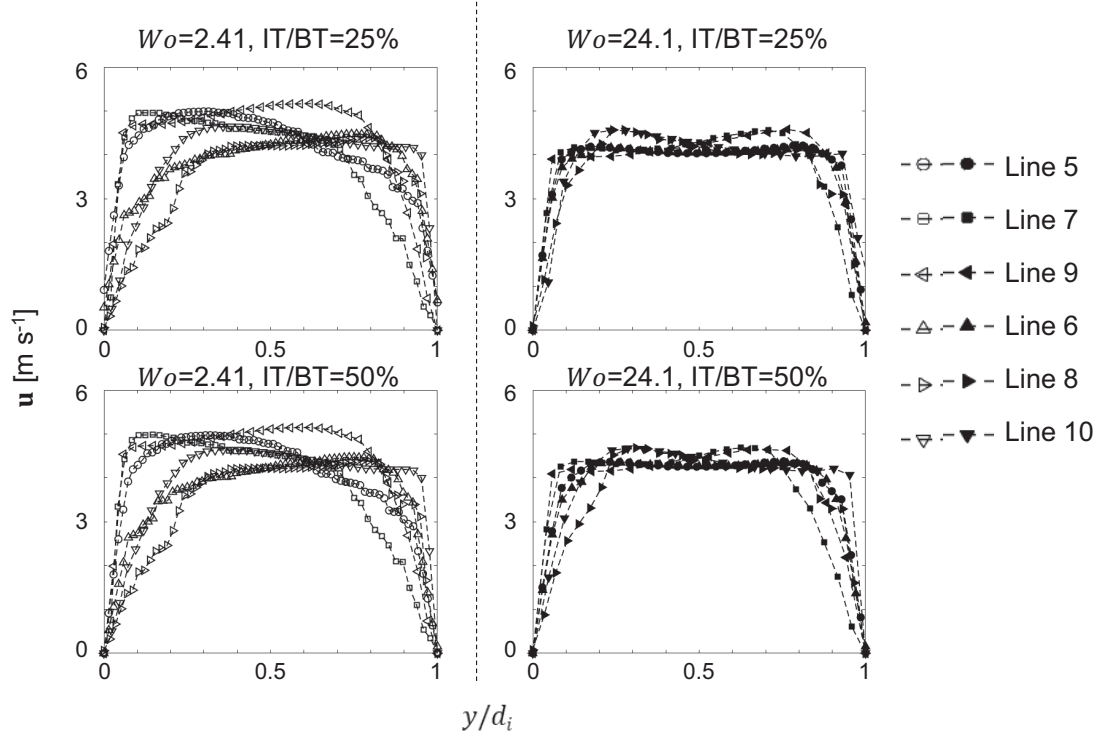


Figure S6. Velocity profiles along coronal plane at in planes 5-10 for varying Wo and IT/BT conditions. Three-dimensional velocity (\mathbf{u}) was extracted along the line across the coronal plane diameter and plotted as a function of non-dimensional diameter y/d_i , where d_i is the airway cross-sectional diameter in i^{th} plane (refer **Table 2**).

TABLE S1. Local Reynolds number (Re_L) and local Womersley number (Wo_L) at each plane listed in Table 2. Re_L and Wo_L were calculated as: $Re_L = \frac{V_L D_L}{\nu}$ and $Wo_L = \frac{D_L}{2} \sqrt{\frac{1}{\nu} \left(\frac{2\pi}{BT} \right)}$, where D_L is the local airway diameter at a given plane, V_L is the average local axial velocity, BT is the breathing time and ν is the kinematic viscosity of air ($\nu = 1.4 \times 10^{-5} \text{ m}^2 \text{ s}^{-1}$).

Location	Description	Re_L/Wo_L									
		$Wo = 2.41,$ IT/BT = 25%	$Wo = 2.41,$ IT/BT = 33%	$Wo = 2.41,$ IT/BT = 50%	$Wo = 7.51,$ IT/BT = 25%	$Wo = 7.51,$ IT/BT = 33%	$Wo = 7.51,$ IT/BT = 50%	$Wo = 24.1,$ IT/BT = 25%	$Wo = 24.1,$ IT/BT = 33%	$Wo = 24.1,$ IT/BT = 50%	
Plane 1	Upper trachea (G0)	6794/2.4	6947/2.4	6894/2.4	6653/7.62	7165/7.61	7418/7.61	6750/24.8	6620/24.8	6602/24.8	
Plane 2	Lower trachea (G0)	4224/2.4	4228/2.4	4227/2.4	4210/7.61	4227/7.61	4247/7.61	4141/24.8	4224/24.8	4224/24.8	
Plane 3	Generation (G1)	3274/1.63	3276/1.63	3275/1.63	2956/5.15	2947/5.15	3237/5.15	3015/16.3	3076/16.3	3079/16.3	
Plane 4	Generation (G1)	3932/1.63	2933/1.63	2934/1.63	3235/5.15	3267/5.15	2984/5.15	3056/16.3	3118/16.3	3121/16.3	
Plane 5	Generation (G1)	3311/1.63	3315/1.63	3313/1.63	2992/5.15	2932/5.15	3264/5.15	3058/16.3	3119/16.3	3119/16.3	
Plane 6	Generation (G1)	2930/1.63	2931/1.63	2932/1.63	3229/5.15	3261/5.15	2980/5.15	3057/16.3	3119/16.3	3120/16.3	
Plane 7	Generation (G2)	2348/1.11	2359/1.11	2354/1.11	2135/3.53	2130/3.53	2324/3.53	2260/11.18	2307/11.18	2311/11.18	
Plane 8	Generation (G2)	2090/1.11	2104/1.11	2096/1.11	2284/3.53	2310/3.53	2118/3.53	2251/11.18	2298/11.18	2302/11.18	
Plane 9	Generation (G2)	2535/1.11	2531/1.11	2533/1.11	2278/3.53	2271/3.53	2489/3.53	2239/11.18	2286/11.18	2290/11.18	
Plane 10	Generation (G2)	2233/1.11	2221/1.11	2230/1.11	2468/3.53	2487/3.53	2270/3.53	2238/11.18	2285/11.18	2290/11.18	

SUPPLEMENTARY MOVIES

Movie 1. Three-dimensional velocity (non-dimensionalized with peak mean flow speed in trachea, U_T) and Q -criterion isosurface at various time points during normal breathing for $Wo = 2.41$ at $IT/BT = 25\%$, 33% and 50% .

Movie 2. Three-dimensional velocity (non-dimensionalized with peak mean flow speed in trachea, U_T) and Q -criterion isosurface at various time points during normal breathing for $Wo = 7.61$ at $IT/BT = 25\%$, 33% and 50% .

Movie 3. Three-dimensional velocity (non-dimensionalized with peak mean flow speed in trachea, U_T) and Q -criterion isosurface at various time points during normal breathing for $Wo = 24.1$ at $IT/BT = 25\%$, 33% and 50% .