Expiration rate drives human airway design.

Analyses of human airway architecture based on calculations of airflow resistance or energy dissipation suggest that the branching pattern is not optimized for minimizing energy loss by flow dissipation during respiration. Airway flow dissipates only a few percent of the total body work during normal breathing, so branching patterns deviate from minimum energy loss to also optimize other physiological needs. Studies of airway performance often record some measure of expiration, such as FEV1 (Forced Expiratory Volume in 1s), because airway constriction during expiration limits the rate of rapid respiration. We posit that lung structure is optimized for the rate of expiration as well as minimum energy loss. By increasing the daughter-to-parent airway diameter ratio (h) from 0.794 (corresponding to the energy minimum for symmetrically branching airways) to 0.85 (the observed value in humans) luminal pressures at airway generations 4-15 were substantially increased during exercise (a 4.5 and 15 cmH2O increase during moderate and heavy exercise, respectively). Values of h somewhat larger than 0.794 help airways remain open during expiration by increasing both viscous pressure drop and convective acceleration pressure drop. Asymmetric bifurcations also exhibit higher proximal airway pressures than symmetric ones, but the improvement was not large.