[Original Research]

CHEST

Does Size Matter When Calculating the "Correct" Tidal Volume for Pediatric Mechanical Ventilation?

A Hypothesis Based on FVC

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BACKGROUND: Tidal volumes standardized to predicted body weight are recommended for adult mechanical ventilation, but children are frequently ventilated by using measured body weight. The goal of this study was to examine the difference in FVC (in milliliters per kilogram [mL/kg]) by using measured body weight compared with predicted body weight in children.

METHODS: This retrospective analysis included outpatient pulmonary function tests (PFTs) from two datasets. Dataset one included 6- to 19-year-old patients undergoing PFTs from the nationally representative Canadian Health Measures Survey. Dataset two included 6- to 20-year-old patients undergoing PFTs at a freestanding children's hospital. FVC mL/kg values were analyzed against BMI *z* scores to show changes in FVC vs BMI between measured and predicted weight.

RESULTS: Dataset one included 5,394 PFTs from the Canadian survey. FVC from measured weight decreased as the BMI *z* score group increased. The median FVC from measured weight was 81.4 mL/kg in the lowest BMI *z* score group and 51.7 mL/kg in the highest BMI *z* score group. FVC from predicted weight increased slightly with increasing BMI *z* score group. Dataset two included 8,472 patient PFTs from clinical measurement. A decline in median FVC from measured weight (from 69.4 to 37.6 mL/kg) as BMI *z* score group increased was also seen.

CONCLUSIONS: FVC differs significantly when standardizing to measured weight vs predicted weight. Obese children have lung volumes reflecting their predicted body weight from height. Children with low or normal BMI have lung volumes reflecting measured body weight. These findings suggest that targeting tidal volume by using the lower of measured and predicted body weights would be the most lung-protective strategy. CHEST 2018; ■(■):■-■

KEY WORDS: ARDS; BMI; children; pulmonary function test

ABBREVIATIONS: CHMS = Canadian Health Measures Survey; CHLA = Children's Hospital Los Angeles; MBW = measured body weight; PARDS = pediatric ARDS; PBW = predicted body weight; PFT = pulmonary function test; V_T = tidal volume

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In the landmark Acute Respiratory Distress Syndrome (ARDS) Network trial, long-term mortality improved when tidal volume (V_T) was limited to an average of 6 mL/kg of predicted body weight (PBW), a surrogate of predicted lung size in normal subjects. The goal of 6 mL/kg PBW was chosen to be lung-protective without causing severe respiratory acidosis in most patients.[1] Subsequently, supported by high-level evidence from further randomized controlled trials,[2-4] lung-protective ventilation strategies for adults recommend targeting V_T according to the patient's PBW based on height and sex. Recently, the Pediatric Acute Lung Injury Consensus Conference also recommended V_T targets based on PBW rather than measured body weight (MBW) and individual lung compliance for children with pediatric ARDS (PARDS).[5]

Using PBW instead of MBW to calculate V_T has a strong physiological basis for obese patients. It is unlikely that lung size increases linearly with increasing body habitus. As lung volumes change with differences in the size of the thoracic cage, reference equations for pulmonary function tests (PFTs) include height,[6-12] and previous investigations have confirmed that height is important to predict lung volume.[12,13] Although obesity is a growing problem in pediatric critical care, a large proportion of children have failure to thrive, in which weight is disproportionally lower than height. Using PBW instead of MBW in these patients could potentially result in higher "acceptable" V_T delivery.

In pediatric mechanical ventilation, despite the physiology and Pediatric Acute Lung Injury Consensus Conference recommendation, MBW is most frequently used for monitoring or setting V_T. Height is less frequently measured in the PICU and may be missing from 60% of medical records for PICU patients.[14,15] This omission makes it impossible to determine PBW correctly.

Although the use of small V_T and low peak pressures has improved mortality in ARDS, there is no clear understanding in PARDS whether decreasing these variables further improves outcomes. V_T in infants and children are variably noted to be normal between 5 and 8 mL/kg and seem to have been determined on MBW (not PBW).[16-18] FVC is a highly reproducible measurement reflecting total lung capacity and hence lung size. The goal of the present study was to determine the difference in FVC (in milliliters per kilogram [mL/kg]) when calculated by using MBW vs PBW in children. In this circumstance, we believe that FVC can be used as a surrogate for V_T. We hypothesized that understanding these lung sizes as a function of different patient body habitus (failure to thrive vs obese) would provide insight into the correct body weight (measured vs predicted) to use for V_T management during critical illness requiring mechanical ventilation.

We collaborated to access nonclinical children's FVC data from the nationally representative Canadian Health Measures Survey (CHMS). These data were compared with FVC data from children studied in the Pulmonary Function Laboratory of the Children's Hospital Los Angeles (CHLA) as outpatients for clinical purposes. We reasoned that although patients measured for clinical purposes may not represent a normal population, they would likely reflect the patient population in the ICU with PARDS. We hypothesized that any changes in FVC with body habitus found in the CHMS children would likely also be found at CHLA.

Materials and Methods

Two datasets were used for analysis, one for the initial evaluation (CHMS) and the second for validation in a clinical population (CHLA).

CHMS Data

Data were collected as part of the first four cycles of the CHMS, conducted between March 2007 and December 2015. The CHMS is designed to provide information on direct health measures at the national level by collecting information from the household population through an in-person interview and a subsequent visit to a mobile examination center. (Details can be found at www.statcan.gc.ca/chms.)

Spirometry measurements were obtained from participants 6 to 19 years of age who had none of the following criteria: pregnant for > 27 weeks, experienced a cardiac insult, major cardiothoracic surgery in the previous 3 months, eye surgery in the past 6 weeks, TB treatment, acute respiratory tract infection, or any other condition that would cause the results to be unreliable, unrepresentative of the usual level of lung function, or the test itself unsafe for the patient.

Respondents were not retained for the statistical analysis of this study if: they were < 6 years of age or older than 19 years; spirometry measures were not valid; FVC and/or FEV_1 was less than the lower limit of normal when calculated by using formulas from the Global Lung Function Initiative incorporating the respondent's age, sex, and height[14]; smoked > 100 cigarettes in their lifetime; had a chronic respiratory condition or symptom; or had a urinary cotinine concentration > 50 ng/mL (first- or second-hand tobacco smoke exposure). All spirometry measurements were conducted by using the same spirometer model with standardized procedures and training of technicians.[19] The study was approved by the Health Canada's Research Ethics Board (project number 2005-0025).

Statistical Analysis of the CHMS Dataset

Continuous data were normally distributed and are presented as mean and 95% CIs of the mean. Using equations based on the Centers for