Simple Predictor of Minute Ventilation: Holliday-Segar Revisited

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Abstract

Background: Minute ventilation (MV) and calorific requirement (CR) are both functions of metabolic demand. The Holliday-Segar formula is a weight-based tool for predicting CR. This study was performed to derive an equation, based on the Holliday-Segar formula, for calculating resting MV from body-weight (BW), which is applicable for all age groups. Methods: MV for BW (obtained from Radford normogram) was plotted against CR for BW (as per Holliday-Segar formula), for BWs ranging from neonates to adults. From the scatter plot thus obtained, best-fit line, with the origin as intercept, was drawn. Linear regression analysis was used to obtain $R^2$ coefficient and $P$ value. Results: The plot of MV against CR yields a straight line passing through the origin with a slope = 46.87. $R^2$ value is 0.98886, $P < 0.001$. Conclusion: MV can be easily and reliably estimated for all age groups from the equation: $MV \text{ (mL/min)} = 47 \times CR \text{ (kcal/h)}$.

Keywords: Body weights and measures, pediatrics, pulmonary ventilation

Introduction

Resting minute ventilation (MV) is an important physiological parameter with a multitude of applications in the day-to-day practice of anesthesia and critical care. Although we know the normal range of MV for adults and nomograms exist for estimation of MV in individuals of various age groups,1-3 there is no fixed formula for deriving the normal value of MV, across all age groups, from any easily measured physical characteristic such as body weight (BW). This is because MV does not follow a strictly linear relation with any such physical characteristic of an individual. If however, we can arrive at an equation that reliably predicts resting MV for all age groups, cardiorespiratory assessment, and ventilator management would be greatly simplified.

Holliday and Segar concluded that the calorific requirement (CR) of an average hospitalized patient, of any age group, can be predicted from BW using the “4:2:1” formula:4

- 4 kcal/kg/h for the 1st 10 kg
- 2 kcal/kg/h for the 2nd 10 kg
- 1 kcal/kg/h for the remainder.

We know that both MV and CR are functions of the metabolic demand of the body. CR can be calculated from BW using the Holliday-Segar formula. Therefore, this study was performed to find out whether it is possible to derive an equation for calculating resting MV from BW, that is applicable for all age groups.

Materials and Methods

This study was designed as a mathematical derivational exercise whereby existing instruments for predicting MV and CR were compared to obtain a correlation. As no actual patients were involved in the study, ethical approval was not required.

MV obtained from Radford nomogram1 was plotted against CR as per the Holliday-Segar formula,4 for BWs ranging from neonates to adults (3, 5, 7, 10, 15, 20, 30, 40, 50, 60, 70, and 80 kg, n = 12). For adults, the MV was taken as the average of the values obtained for males and females from Radford nomogram.

From the scatter plot thus obtained, best-fit line, with the origin as intercept, was drawn. Linear regression analysis was performed to obtain $R^2$ coefficient (regression coefficient)

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using Microsoft Excel 2013 (Microsoft Corporation, Redmond, WA, USA) for Windows. \( P \) value for the obtained \( R^2 \) coefficient was calculated using Social Science Statistics (http://www.socscistatistics.com) open access online calculator. The value of \( P < 0.01 \) was considered to be statistically significant.

RESULTS

The chosen BWs for analysis, the MV for each BW derived from Radford nomogram, and the corresponding CR from Holliday-Segar formula have been compared [Table 1].

The plot of each value of MV against the corresponding CR yielded a straight line passing through the origin with a slope = 46.8 [Figure 1]. \( R^2 = 0.98968 \) (\( P < 0.001 \)).

DISCUSSION

Mechanical ventilation needs to be controlled to maintain normal oxygen and carbon dioxide tensions in the blood. Existing ventilation guides, such as Radford’s nomogram,[1] Nunn’s \( \text{CO}_2 \) predictor[2] and the Adelaide ventilation guide,[3] are based on experimentally obtained data, and require plotting BW on that particular chart to obtain the corresponding MV. Although these nomograms are very useful for adjusting ventilator settings in children, especially in resource poor settings where end-tidal \( \text{CO}_2 \) measurement and blood gas analysis may not be readily available, their practical use is limited as the required charts are too complicated to be memorized, and not often at hand.

Our analysis shows that resting MV has a strong co-relation with CR, as calculated by Holliday-Segar formula, over all ages from birth to adulthood. This is plausible as both are functions of metabolic demand of the body.

Baseline MV can be easily calculated form the equation:

\[
\text{MV (in mL/min)} = 47 \times \text{CR (in kcal/h as per Holliday-Segar formula)}
\]

This simple equation gives us a physiological basis for estimating resting MV from BW, without having to rely on a nomogram chart. The value so obtained can be used for initial ventilatory settings in infants, children, as well as adults of all body sizes. It is, however, important to account for changes in the ratio of dead space ventilation to alveolar ventilation during various ventilatory strategies in the ICU or under anesthesia.[5]

As a corollary, normal resting cardiac output (CO) for BW can also be estimated from the same equation as CO nearly equals MV in resting state to maintain a ventilation to perfusion (V:Q) ratio of 1. Further studies may be conducted to validate this.

CONCLUSION

This study shows that resting MV can be easily and reliably estimated for all age groups from the equation: MV (mL/min) = 47 \times \text{CR (kcal/h)}.

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Conflicts of interest
There are no conflicts of interest.

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