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Validating a new formula for weight estimation in pediatric cancer patients

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ABSTRACT

Child resuscitation requires actual weight measurement if possible. Multiple pediatric weight estimations are now available. Garwood and McEwen developed a new formula (age in months/4) +6. The aim of the study is to validate this formula versus advanced pediatric life support formula and Shann formula among pediatric cancer patients. Cross sectional study was conducted in 508 pediatric patients aged 1 to 16 years attending outpatient clinic at the children cancer hospital (57357 hospitals). Their age and actual weight were recorded. Accuracy of weight estimation was done using mean bias, 95% agreement, mean percent error, and estimation within 10 and 20% from actual weight. The mean bias from actual weight of the new formula was 1.3 kg versus -2 kg for Shann formula. The new formula outperformed the other two formulae in the age group 11 to 16 with a mean bias 0.8 kg and percent error -5.9% versus 8% for Shann formula. The new formula is among the more accurate age-based weight estimation formulae especially for older children. It is an acceptable option for estimating children's weight.

Keywords: Advanced Pediatric Life Support formula, Garwood and McEwen formula, pediatric weight estimation, Shann formula.

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INTRODUCTION

Accurate pediatric weight determination is the corner stone in child resuscitation in the emergency department (ED). Knowledge of weight is critical in drug dosage calculation, determination of tube size, intravenous drug administration, defibrillation and other life-saving measures (Kaushal et al., 2001; Selbst et al., 1999).

The “gold standard” method for weight determination is to weigh the child on a scale, but this requires fixed equipment and adequate time (Argall et al., 2003). In developing countries and in emergencies, limited time or resources hinders actual weight measurement (Varghese et al., 2006; Krieser et al., 2007).

In the past decades, multiple methods for estimating weight are based on age alone or on a combination of age and height (Black et al., 2002; Lubitz et al. 1998; Mackway-Jones et al., 2001; Vilke et al., 2001; DuBois et al., 2007; Tinning and Acworth, 2006; Luscombe and Owens, 2007). Age-based estimation methods are more advantageous as it is simple, reliable and fast. In addition, it is useful in preparing dosage and dilution for drugs and fluids even before arrival of expected seriously ill or injured patients to the ED (Vilke et al., 2001). Recently, the accuracy of these methods has been challenged (Black et al., 2002; Theron et al., 2005; Nguyen et al., 2007).

One method of weight estimation commonly used all over the world is Advanced Pediatric Life Support (APLS) formula. This is applicable to children aged 1 to 10 years. It is calculated as follows: Weight estimation in kg = 2 (age in years + 4) (Mackway-Jones et al., 2001). Unfortunately this formula has proven to be inaccurate nowadays (Black et al., 2002), as it gives rise to a significant weight underestimation (Luscombe and Owens, 2007).

In Egypt, anaesthetists used Shann formula (Shann, 2005). It is divided into two formulae, one for age group 1 to 9 years [weight in kg = (Age × 2) + 9], and the other for age group >9 years (weight in kg = Age × 3).

Garwood and McEwen in 2011 have developed and validated a new formula for weight estimation in United

Kingdom and emphasized that the new formula yields a better estimation of pediatric weight than the more commonly used APLS formula. It is calculated as follow: Weight estimation in kg = (age in months/4) + 6 (Garwood and McEwen, 2012).

Although many authors have discussed the use of different formula to estimate the child' weight, little is known about pediatric cancer patients where cachexia may be a prominent sign or they may be overweight by the large solid abdominal tumor or edema from corticosteroid therapy (Pietsch and Ford, 2000). As drug dosing depends mainly on lean body mass rather than total body mass, estimation of body weight using as possible an accurate formula is essential (Stucky, 2003).

Rationale

Most methods to estimate weight from age are based on western pediatric populations. The aim of this study is to validate the new formula versus the commonly used formulae in Egyptian pediatric cancer patients.

PATIENTS AND METHODS

The study was approved by the local ethics committee. Confidentiality of the data was respected.

Study design and duration

Cross sectional study was conducted in Children cancer hospital (57357 hospitals) in Egypt over a period of 2 months (from June to August, 2012).

Sampling type and size

A convenient sample of 508 pediatric cancer patients was included in this study after exclusion of duplicate cases. The patients were recruited from preoperative assessment clinic of the hospital. All the patients should fulfill the following eligibility criteria:

Inclusion criteria: Any pediatric patient aged 1 to 16 years.

Exclusion criteria: All children requiring rapid emergency care, unstable and critically ill. Subjects were excluded if they had any medical condition that would affect their weight: amputation, dwarfism, or neurologic defects (e.g., cerebral palsy).

Methods

Age of the child was recorded in years and months. For Shan and APLS formulae, the age is rounded down to the nearest year. Children were weighed without coats or shoes, by a fixed senior nurse. Their weights in kilograms were measured using the same set of calibrated electronic scales. Weights were recorded to the nearest 0.1 kg.

Statistical analysis

Data were coded and entered on SPSS version 15. Estimation of weights was also calculated and recorded using the new Shann and APLS formulae. After checking for data normality, descriptive statistics [mean, standard deviation (SD), median, 25% and 75 percentiles, range, numbers and proportions] for age, gender, and weight were done. Mann-whitney test was used to compare males and females. Spearman correlation between actual weight and all estimation methods was performed. Percent error (PE) between actual weight and each estimated formula was also calculated. A percentage error of 10% or greater was considered significant.

Agreement between the various weight estimation methods and actual weight (gold standard) was assessed by calculation of mean bias, SD, 95% limits for agreement which are the bias plus/minus two standard deviations of the differences and 95% confidence interval using Bland-Altman techniques (Bland and Altman, 1995). We also report the proportion of cases that were accurate in weight estimation to within 10 and 20% of measured weight. Analysis was performed using SPSS 15 statistical software with a P value <0.05 considered significant and MedCalc for Bland-Altman plots.

RESULTS

This study was conducted in 508 patients who were attending the preoperative assessment clinic in the hospital during the period of work. All the patients were Egyptians. Males represented 60.8% (309 patients) while females constituted 39.2% (199 patients). Median age was 7 (4 to 10) years. Majority of children 77.6% (394 patients) were under 11 years old. Measured weight ranged from 6 to 115 kg (median 22.1 kg). Estimated weight by new formula ranged from 9 to 45.8 kg (median 26.3 kg). Weight estimated by Shann formula ranged from 11 to 48 kg (median 23 kg), while APLS formula estimated weight ranged from 10 to 40 kg (median 22 kg). Although males weighed slightly more than females, the results were not statistically significant. Accordingly, the data was analyzed collectively after that. The previous results are shown in Table 1.

There was good correlation between estimated weight and actual weight with an *r* value of 0.9 for the new formula, and 0.88 for Shann formula and APLS formula. All the correlation was statistically significant ($p < 0.0001$).

Figures 1, 2 and 3 demonstrated the differences from actual weight for the three methods of estimation, versus average of actual weight and estimated (Bland-Altman plots). The mean bias was 1.3 kg for the new formula (95% CI 0.6 to 1.9 kg), -2.0 kg for the Shann formula (95% CI -2.7 to -1.2 kg), and -3.9 kg for APLS formula (95% CI -4.7 to -3.2 kg). A negative bias is noted, with last two methods underestimating the actual weight. Predictive accuracy was superior for the new formula.

The mean percent error of our study demonstrated that the new formula over estimate the weight by 8.6% error while APLS formula and Shann formula underestimate the weight by 8.5%.

After calculating the percent error (PE) of all formulae, it was classified as PE<10%, 10 to 20%, and >20%. The new formula estimated weight within 10% error was 82.7% (higher than other formulae). The percentage error

Table 1. Distribution of weight (actual and estimated) in relation to sex.

Weight (kg) \ Sex	Males (309)	Females (199)	P value**	Total
Actual weight *	22 (16-34)	21 (15-35)	0.43	22.1 (15-35)
Estimated weight by new formula	27 (18-36)	25 (17-36)	0.31	26.3 (18-36)
Estimated weight by Shann formula	23(17-30)	21 (17-30)	0.25	23 (17-30)
Estimate weight by APLS formula	22 (16-28)	20 (16-28)	0.25	22 (16-28)

*median (25 to 75 percentiles), ** Mann-whitney test.

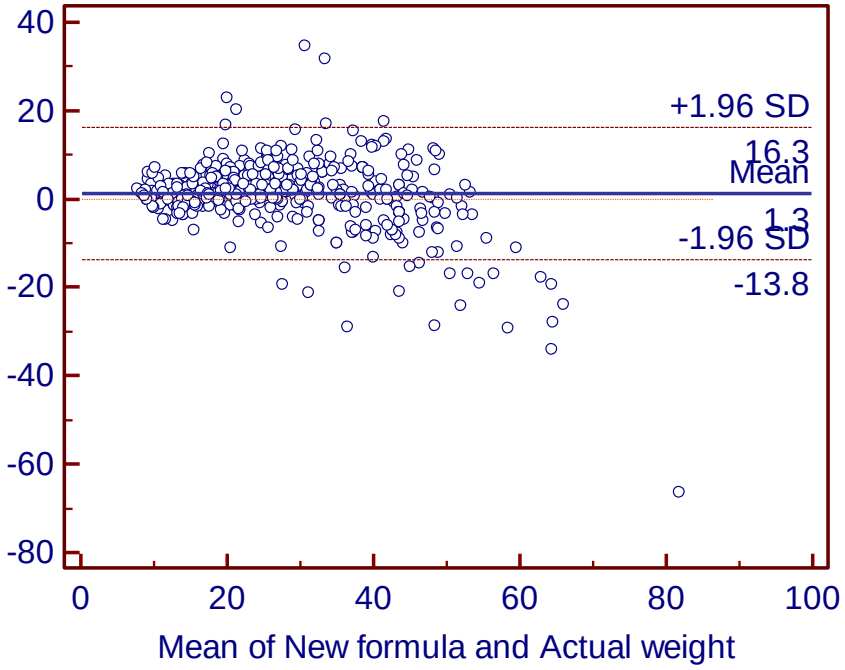

Figure 1. Bland-Altman plots for predictive accuracy of new formula weight-estimation method (kg).

20% or greater was 7.7% for the new formula. A percentage error of 10% or greater was considered significant.

Data were classified into two groups (1 to 10 and 11 to 16 years) in order to test the validity of the new formula among those age groups.

In age group (1 to 10 years), Shann formula yield the least mean error by Bland-Altman plot (-0.6 kg) with 95% limits of agreement (-12 to 10.7 kg) and least mean percent error from actual weight (-5.3%), while in age group (11 to 16) the new formula showed the least mean error (0.8 kg) with 95% limits of agreement (-25.5 to 23.8), and percent error (5.9%) (Table 2).

Calculation of the different estimated weights within 10% of actual weight demonstrated that: 36% of new and Shann estimations versus 33% of APLS estimation were accurate within this percent. While calculation within 20% from actual weight clarified that: 61.2% vs.64.45 vs.63.2% of the new, Shann and APLS estimations, were accurate within this percent.

According to different age group, 39.8% of weight estimations by Shann formula were within 10% of actual weight in age group (1 to 10 years). On the other hand, the new formula showed highest percentages within 10 and 20% of actual weight (36.8 vs. 62.3%) in age group (11 and 16). The results are illustrated in Table 3.

DISCUSSION

In emergency situations, it is often impossible to determine a pediatric patient's weight by using a scale, so it is often estimated (Hofer et al., 2002).

As such, a variety of methods have been developed to rapidly estimate a child's body weight using age as the only variable (Argall et al., 2003).

APLS formula is now thought to significantly underestimate weight (Luscombe and Owens, 2007).

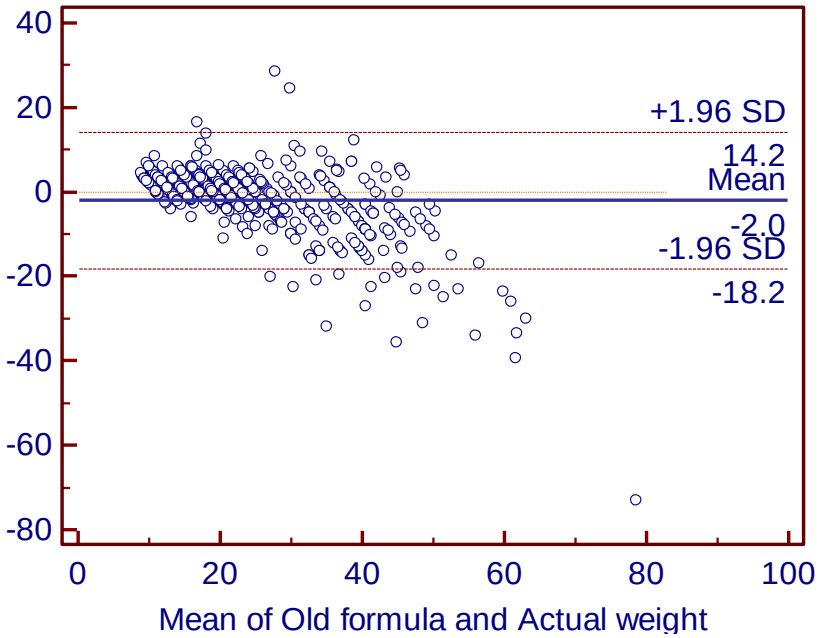

Figure 2. Bland-Altman plots for predictive accuracy of Shann formula weight-estimation method (kg).

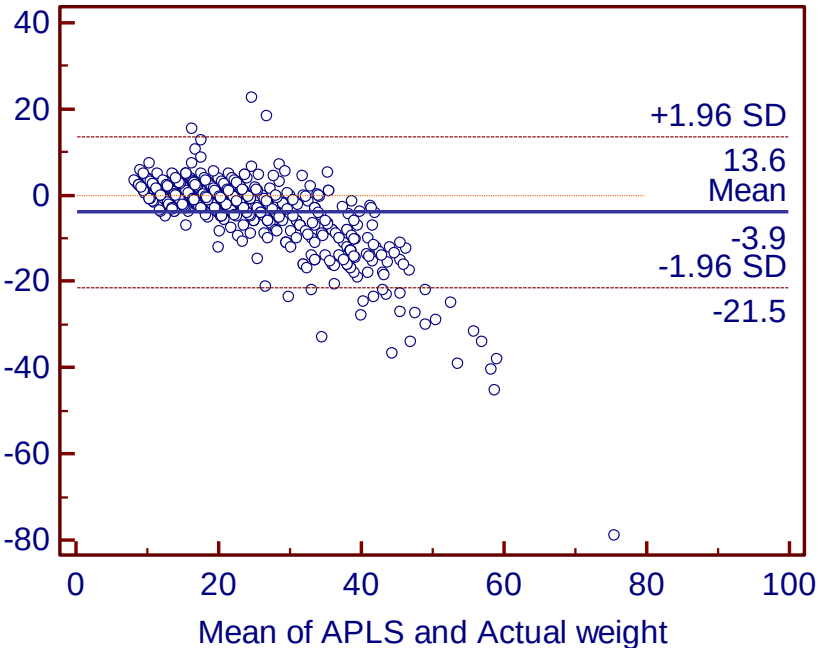

Figure 3. Bland-Altman plots for predictive accuracy of APLS formula weight-estimation method (kg).

Shann formula which is commonly used among pediatric patients in Egypt, and New Zealand (Theron et al., 2005) also proved inaccuracy in weight estimation (Park et al., 2012).

According to Bland-Altman plot, the new formula overestimates the weight by 1.3 kg, while Shann and APLS formulae underestimate the weight by 2.0 and 3.9 kg respectively. Thirty-six of the new formula estimates were within 10% of actual weight. 62% of the new formula estimates were within 20% of actual weight. In the study conducted by Kelly and co-workers (Kelly et al., 2001) who compared the actual weights versus Luscombe

Table 2. Mean bias, mean percent error (MPR) and 95% CI from actual weight in relation to age groups.

Age group / Formulae	Patients aged from 1-10 (394 patients)		Patients aged from 11-16 (114 patients)	
	Mean bias in kg (SD) (95% CI)	MPE (95% CI)	Mean bias in kg (SD) (95% CI)	MPE (95% CI)
New formula	1.9 (5.3) [1.3-2.4]	-14.4% [-17.2%-11.6%]	0.8 (12.5) [-3.2-1.6]	-5.9% [-12.7%-0.84%]
Shann formula	-0.6(5.7) [-1.2-(-0.007)]	-5.3% [-8.5%-(-2.7%)]	-6.7 (12.6) [-9.1-(-4.4)]	8.0% [2.1%-13.9%]
APLS formula	-1.7 (5.8) [-2.3-(-1.10)]	0.6 [-1.8% - 3.2%]	-11.6(12.7) [-13.9-(-9.3)]	19.4% [14.3%-24.6%]

Table 3. Percent distribution of different estimated weight within 10 and 20% of actual weight.

Age groups / Formulae	Patients aged from 1-10 (394 patients)		Patients aged from 11-16 (114 patients)	
	Within 10% of actual weight No (%)	Within 20% of actual weight No (%)	Within 10% of actual weight No (%)	Within 20% of actual weight No (%)
New formula	141 (35.8)	240 (60.9)	42 (36.8)	71 (62.3)
Shann formula	157 (39.8)	259 (65.7)	29 (25.4)	68 (59.6)
APLS formula	149 (37.9)	278 (70.6)	23 (20.2)	43 (37.7)

[Weight = 3 (age) + 7] (Ali et al., 2012), Advanced Pediatric Life Support (APLS), and best-guess estimations [(2 × age) +10]. The Luscombe formula showed a mean difference of 0.66 kg from actual weight, and 45% of its estimates were within 10% of actual weight but accuracy deteriorated as weight increases, especially for children older than 5 years. Best guess was second to Luscombe estimation with a mean difference from actual weight of 0.7 kg, and 42% of its estimates were within 10% of actual weight, but it still has a tendency to overestimate weight, particularly in children with lower body mass index. APLS estimates showed a mean difference of 4.3 kg and 34% of its estimates were within 10% of actual weigh.

The mean percent error of our study demonstrated that the new formula over estimate the weight by 8.6% error while APLS formula and Shann formula underestimate the weight by 8.5%. Those results are comparable to Park and others who found the mean percent error of APLS formula is (-11%) and of Shann formula is -8.5 (Park et al., 2012). Our result was not consistent with Garwood and McEwen (2012) who developed the new formula and recorded lower mean percent error for their formula (5.6%). Such a difference may be attributed to the nature of the studied patients where our patients are cancerous patients.

Although the mean percent error of the new formula dose not exhibit advantage over other formulae, but classification of MPE into less than 10% error, 10 to 20%, and more than 20% clarified that the estimated weight by the new formula within 10% error was higher than Shann and APLS formulae.

Weight varies widely among different age group due to different growth velocities. As a result, no single formula can be used accurately throughout different age group (Tinning and Acworth, 2006). Most of the formulae developed in the past decades estimated weight of children in age group ranging from 1 to 10 years (Ali et al., 2012). Little is known about weight estimation in older age group.

Unlike the other formulae, the new formula showed better estimation of weight in older age group (11 to 16 years). The new formula showed the least mean error (0.8 kg), and percent error (5.9%). APLS formula had the highest mean percent error in this age group (19.4%). This finding is consistent with Thompson et al. (2007) who found the APLS formula underestimates weight by a MPE of 19.9% in school-aged children (5 to 14 years).

Limitation

The study excluded seriously ill children and includes only cancer pediatric patients where underweight may be a prominent sign. These factors might have introduced bias. The sample is derived from a single site, and might not be generalizable to other settings. Another limitation will be the necessity to add a third formula for infants.

Conclusion

In comparison to other weight estimation formulae, the new one performed well especially in older age group with a tendency to overestimate weight.

RECOMMENDATION

We recommend using Shann formula for age group less

than 10 years old and the new formula for the older children. Further studies should be done to validate the formula among patients without cancer.

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