A NEW METHOD OF COMPUTING THE VERTEBRAL HEART SCALE BY MEANS OF DIRECT STANDARDIZATION

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Abstract:

Introduction: The vertebral heart scale (VHS) method described by Buchanan is considered a good objective radiographic measurement to detect cardiac enlargement in dogs.The methodology used can be time-consuming and may benefit from simplification at the time of measuring it.

Objectives: The aim of this study was to describe and compare a simplified VHS computation method based on the previous methodology (Objective VHS) with the methodology used in the original study (Buchanan VHS).

Methods: Objective vs. Buchanan methodology of computation of the VHS was compared in 42 dogs: 14 healthy dogs and 28 dogs with Mitral Insufficiency. In the case of Objective VHS, the sum of the length of the long and short axes of the cardiac silhouette obtained in centimetres using a metric ruler was subsequently converted into units of vertebral length by means of a direct standardization method. The Buchanan VHS was obtained as previously described.

Results: No significant differences in VHS values were found between methodologies in all dogs.A strong positive correlation between Objective and Buchanan VHS was found (0.99).

Clinical significance: The use of direct standardization based on an unit conversion allows obtaining Objective VHS values without transposing long and short axes to the cranial edge of T4.

INTRODUCTION

Radiography is a useful tool in the diagnosis of canine cardiac disease, and different authors[1, 2, 3, 4, 5, 6,] originally proposed different methods to evaluate the presence of cardiomegaly.

Subsequently, other authors[7], described the Vertebral Heart Scale (VHS) as a new index to assess cardiac size. They defined the cardiac long axis (L) as the line extending from the heart base to the apex of the cardiac silhouette, and the cardiac short axis (S) as the line perpendicular to the previous one and running across the zone of maximum width of the same silhouette. Both axes were repositioned over the thoracic vertebrae starting from the cranial aspect of the fourth thoracic vertebra (T4) and expressed as total units of vertebral length (v). Their sum defined the VHS. The normal range was

9.7 ± 0.5 vertebrae. A variation on the methodology of obtaining the VHS was published later on by one of the authors[8]. In dogs with a large left atrium and elevated left caudal lung lobe bronchus caudal to the tracheal bifurcation, the (L) measurement was obtained from the ventral edge of the elevated bronchus to the apex of the cardiac silhouette and the (S) measurement was obtained at the level of the dorsal border of the caudal vena cava to reflect the increase in dimensions of the cardiac silhouette. Subsequently, some studies related to the VHS[9, 10,11,12] demonstrated that a higher VHS normal value (10.5v) could be expected with several breeds (Boxer, Labrador Retriever, Whippet, Cavalier King Charles Spaniel, Greyhound). One of these studies[10] described breed-specific ranges for six breeds in which the mean VHS was higher than 10.5 in three out of those six breeds: Cavalier King Charles spaniel (10.6 +/- 0.5 v), Labrador Retriever (10.8 +/- 0.6 v) and Boxer (11.6 +/- 0.8 v). In particular, measurements of Boxer dogs showed a higher vertebral heart scale than other breeds. Furthermore, females had smaller mean values than males. As a consequence, interbreed differences, and possibly gender, should be taken into consideration when evaluating the possibility of cardiomegaly on the basis of the VHS.

To date, the VHS remains the most objective radiographic measurement to detect cardiac enlargement in dogs. The methodology used in previous publications to obtain this measurement effectively measures the long axis (L) and short axis (S) in millimetres[7,8,13].

In this study we describe an Objective VHS, an adaptation and simplification of the methodology used in previous publications (“Buchanan VHS” from now on in this publication). The Objective VHS uses a direct standardization method to obtain the VHS value. . This simplified method could lead to an increase in VHS use by practitioners, particularly when working with digital radiography.

Objectives of the study:

1) to describe and compare the Objective and the Buchanan VHS computation methods and 2) to assess the concordance between them.

MATERIALS AND METHODS

Animals

The study consisted of a retrospective analysis of 42 thoracic radiographs from privately owned dogs divided into two groups: Group A: 14 healthy dogs, 8 males and 6 females, with a mean age of 4.5 years and of 4.8 – 19 kg weight range, used as control group. Breeds represented in this group were mixed-breed (n=10) and one of each of the following: French Bulldog, Pug, Cavalier King Charles Spaniel and Pekingese.

Group B: 28 mixed-breed dogs with Mitral Insufficiency (17 males and 11 females, with a mean age of 8.3 years and of 5.1 – 21.2 kg weight range); all animals underwent complete radiographic and echocardiographic examinations. The animals had been seen at one of the following centres: Betulia Veterinary Clinic, Barcelona, Spain; Survet Diagonal, Carvet, Barcelona, Spain and Gran Sasso Veterinary Clinic, Milan, Italy.

All dogs underwent a complete clinical evaluation including physical examination, blood pressure, CBC and biochemistry panel.

In addition, a set of 9 animals, that were part of the study population, was included into a validation protocol comparing both measuring methodologies. Three observers with different expertise at assessing thoracic radiographs (lecturer, PhD student and clinical practitioner) evaluated each animal in three different occasions on three different days.

The cases were randomly presented to each observer in each occasion. Each case was evaluated using both radiographic measuring methodologies.

Radiographic Measurements

Only good quality right lateral recumbent thoracic radiographs were used to obtain the measurements (through photographs of the analog images or digital radiographs), aiming to minimize any difficulties in identifying relevant anatomical landmarks.

All images were exported into a commercially available computer software[a] that was used to ensure a 90-degree rotation between L and S; this offered continuity through the measuring process, regardless of the origin (analog or digital) of the radiographs.

The **Buchanan method** to obtain the VHS value was performed as follows:

L and S were measured as previously described[8] (Figure 1).

Using computer software[a], the long axis of the VHS was obtained selecting "line" under the drawing menu. Subsequently, a line (L) was drawn from the ventral border of the left main stem bronchus at the carina to the most ventral point of the cardiac apex.

To obtain the short axis, L was selected, duplicated and, through the "Size and position" option for this line, a 90 degree rotation was applied. After closing the window "Size and position", the second line, or S distance, was repositioned at the dorsal boundary of the caudal vena cava at the widest craniocaudal region of the cardiac silhouette.

The length of S distance could be adjusted to the size of the cardiac silhouette by first selecting it with the right mouse button. Clicking then with the left mouse button while pressing "Shift" to maintain its angulation, its length could be adjusted.

Both distances were repositioned over the thoracic vertebrae starting at the cranial aspect of the fourth thoracic vertebra, running parallel to the long axis of the vertebral column; to do so, both distances were copied and pasted and, using the rotate option previously described, positioned parallel to the vertebral column . The short and long axis dimensions were then added to yield the VHS. The sum of the long and short axes was expressed as total units of vertebral length to the nearest 0.1 vertebra (v)[7,8].

The Objective (Direct Standardization) method to calculate the VHS was performed as follows:

Measurements were obtained using a ruler[b].

A 5-vertebrae long index of vertebral body length was obtained by measuring in cm the distance from the cranial aspect of T4 to the caudal aspect of T8, running parallel to the vertebral column. The cardiac long and short axes obtained as previously described were then measured in cm and translated onto VHS units (to the decimal point) by the statistician by means of unit conversion. (Figure 2) using the following equation:

$$\frac{A}{B} = \frac{C}{X}$$

where the variable to be evaluated is in the right-hand denominator. The unit conversion states that:

$$X = \frac{BC}{A}.$$

A = T4-T8 distance (cm)

B = Sum of long and short axes (cm)

C = T4-T8 distance expressed as total units of vertebral length (v), equivalent to what the Buchannan method would have done when transferring the L and S measurements to the vertebral column. The distance between T4 and T8 in units of vertebral length measures 5 and is considered a statistical constant in this equation.

X = Sum of long and short axes (VHS) expressed as total units of vertebral length (v)

Example: (Figure 2)

A= 4.52 cm

B= 4.89 + 3.57 = 8.46 cm

C= 5v

X=(8.46 x 5)/4.52 = 9.36 v

Measurement improvement: Bias correction

In order to correct some mild proportional bias between the Objective VHS method and the Buchanan VHS method (see results and discussion sections), a simple correction could be used, if desired:

$\text{OBJECTIVE VHS}_{\text{Bias corrected}} = 0.74 + 0.93\text{ X}$

Comparison of measurements

Considering that both methods use the long and short axis measurements, and in order to compare both methodologies eliminating a possible repeatability bias, these measurements (L and S) were only obtained in one occasion per evaluation (i.e. once for each case in the Objective VHS-Buchanan VHS comparison study and once for each case-observer - different day combination in the validity assessment

Statistical analysis

Statistical analysis was performed using a commercially available software package[c].

Summary descriptive indexes (means, standard deviations and the corresponding minimum and maximum values) were obtained for the two primary variables (Objective VHS and Buchanan VHS) in each subgroup population (Normal and MI dogs). The concordance between both measurements was tested by means of 1) Pearson Correlation together with a simple regression model and 2) evaluated graphically by means of a Bland-Altman plot (Figure 3). The variance components for this primary analysis (population and intra-case) were computed using a mixed model using case as a random factor. The internal and external validity of both measurements was examined without applying any bias correction using the group of cases, which were randomly evaluated by three different observers on three different days. The different variance components (population, inter-observer and intra-observer variances) were obtained using a mixed model for each method including the observer and case as random factors.

Statistical significance was determined by the criterion $p < 0.05$.

RESULTS

Descriptive statistical analysis

The mean Objective VHS value was 10.46+/-0.61v (9.28, 11.35v) in Group A (Normal dogs), 12.14+/-1.28 v (9.91, 15.29v) in Group B (MI dogs), and 11.58+/- 1.35v (9.28, 15.29v) for the complete study population.

Mean Buchanan VHS value was 10.49+/-0.59v (9.30, 11.30v) in Group A, 12.04+/-1.21v (9.90, 15.10v) in Group B and 11.52+/-1.27v (9.30, 15.10v) for the complete study population.

No significant differences between mean Objective and Buchanan VHS values were detected for the two groups and for the study population as a whole.

Concordance between measurement methods

A significant positive Pearson's correlation (0.99, $p<0.0001$) was found between Objective and Buchanan VHS in normal dogs and dogs with mitral insufficiency (0.99, $p<0.0001$) and in the complete study population (0.99, $p<0.0001$).

The concordance between the two measurements is shown graphically using a Bland-Altman plot in Figure 3. From a descriptive point of view, the mean difference in absolute value is 0.146 (v), while the largest difference does not exceed 0.5 (v), which represents less than 5% of imprecision between the two methods. The raw variability for the difference between methods is 0.033 and the corresponding variance component was 0.018. A proportional bias is observed, however, indicating that similar results are obtained for low values by both methodologies, whereas the Objective VHS produces slightly larger values than the Buchanan VHS when the observed magnitude becomes larger. The magnitude of this mean bias is less than 2% in absolute terms for the most extreme cases. Consequently, if a more reliable reproduction of Buchanan VHS was needed, a simple correction to the computation of the objective VHS could be applied:

$$\text{OBJECTIVE VHS}_{\text{Bias corrected}} = 0.74 + 0.93\ X$$

This correction is obtained from a direct linear regression taking the Buchanan VHS as the response variable and the Objective VHS as the explanatory variable

Validity assessment

Table 1 shows the results of the analysis assessing and comparing the validity of both methods, as described in the material and methods. The components of variance for both methodologies are very similar. The population variance component is smaller for the Buchanan VHS method indicating that the objective VHS values are more widely spread. The inter-observer variability is negligible with both methodologies. Finally, the assessment of intra-observer variability offered again similar results for both methodologies, although they were slightly more variable for the Buchanan VHS. The magnitudes of the inter-observer variance component show that there is a natural imprecision in the measuring process (0.072 and 0.086 for Objective and Buchanan methods, respectively), which is considerably larger than the intra-case variability associated to the difference between methods (0.018, as shown previously).

DISCUSSION

VHS variability factors

The vertebral Heart Scale is considered the most objective radiographic measurement for detecting cardiac enlargement in dogs, but several factors can lead to variability in its results. Previous studies[13] have shown that the long axis measurement is more variable than the short axis measurement. This is due to the difficulty in accurately determining the exact location of the apex of the cardiac silhouette due to skin folds, superimposed ribs, pleural effusion and/or the most cranial portions of the liver[14], as well as the effects of the presence of neighbouring fat and cardiomegaly, when present.

The presence of cardiogenic pulmonary oedema can significantly hinder the measurement of the VHS because of the associated perihilar increase in radiopacity, potentially also obscuring the caudal vena cava. In previous studies[13], pulmonary oedema did not introduce variation in the long axis measurements. In our opinion, it is the accuracy of the short axis measurement that can be particularly compromised by the presence of pulmonary oedema as S is obtained using the caudal vena cava as an anatomical landmark, either at a point halfway from its ventral to its dorsal border[13], or from its dorsal border[8]. Radiographs with radiographic changes compatible with left sided congestive failure / pulmonary oedema were therefore excluded from our study. Radiographic technique also plays an important role in the measuring process of the cardiac axes, particularly the short axis, as alterations in the position of the caudal vena cava can modify this measurement's starting point.

Finally, inter-observer variability at the time of measuring the VHS and the known considerable overlap between the VHS values of dogs with cardiac disease and the reported normal ranges should also be taken into consideration with respect of the variability of VHS values[9].

Descriptive statistics and concordance

In this study, the mean values of Objective and Buchanan VHS in **normal dogs** were 10.46+/-0.61 v (9.28, 11.35v) and 10.49+/-0.59v (9.30, 11.30v) respectively. No significant differences were found between Objective and Buchanan VHS means in normal dogs.

No significant differences were found either between Objective and Buchanan VHS means in dogs with **mitral insufficiency**.

These values also reiterate the overlap between the VHS values of dogs with cardiac disease and the reported normal ranges, as previously published[9].

There were no significant differences between means of Objective and Buchanan VHS for two separately groups and for the complete study population.

A significant positive concordance between Objective and Buchanan VHS values in normal dogs, dogs with mitral insufficiency and for the whole study population was found (0.99). In our opinion, these results can encourage practitioners to calculate the VHS using the Objective method in a clinical setting.

The concordance between both methods is also confirmed by the fact that the difference in the values obtained by both methodologies is of a smaller magnitude than that associated to intra-observer variability. Having said that, a slight proportional bias was found (i.e. for those patients with VHS values towards the higher end of the spectrum of results, the obtained values of the Objective VHS tended to be higher than those obtained using the Buchanan VHS). This bias may be associated with the fact that the T4-T8 distance was always used for the former, whereas a longer portion of the vertebral column is used with the latter in cases with severe cardiomegaly. The potential difference in vertebral body length and intervertebral disc space width in areas caudal to T8 was considered a potential explanation. This hypothesis should be confirmed in further studies.

It must be emphasised that this bias can be eliminated using the simple correction included in the results' section.

Direct Standardization

We propose the unit conversion as a mathematical formula to accurately measure the Objective VHS without the need to transpose the long and short axes to the cranial aspect of the body of the fourth thoracic vertebra. This simplified methodology decreases slightly the variability introduced into the VHS value from the transposition of these measurements to the vertebral column, despite this variability not being statistically significant. Moreover, the validity assessment has shown that intra-observer variability is slightly lower when using the Objective VHS instead of the Buchanan VHS.

The internal and external validity of both measurements was examined without applying any bias correction in order to preserve the original measurements. If the correction had been applied, the internal validity of the Objective VHS would have been even lower.

Minimal differences were found between the values obtained by the three different observers with diverse expertise. In this study, the values obtained using the Buchanan VHS and the Objective VHS were independent from observers' expertise.

The direct standardization method evaluates cardiac size irrespectively of the size of the patient and its thoracic conformation, as the Buchanan VHS does. If a more precise measurement was required, this objective VHS can be bias corrected using a simple transformation.

The Objective VHS is based on the relationship between the distance from the cranial aspect of T4's vertebral body to the caudal aspect of T8's vertebral body (measured in cm) and the measurements of the long and short axes of the cardiac silhouette. If the long axis and short axis of the cardiac silhouette as well as the T4-T8 distance are quantified in cm, the final and objective VHS value can be obtained without the need of any transposition.

The proposed formula for the calculation of the Objective VHS is particularly useful for those clinicians using digital radiography. The use of a digital version of the formula would allow a very quick calculation of the VHS. The authors feel this is the main and most significant advantage of this new methodology.

When digital radiography is not available, clinicians can either calculate the Buchanan (Clinical) VHS using a sheet of paper as previously described[7,10] or the Objective VHS measuring L, S and T4-T8 with a metric ruler and calculating VHS value using the direct standardization formula.

Conclusion

No significant differences in VHS values were observed when using the Objective and the Buchanan VHS methodologies. Concordance between the Objective and the Buchanan VHS methods was confirmed. The use of direct standardization based on unit conversion helps in calculating the Objective VHS values without the need of transposing the measurements of the long and short axes of the cardiac silhouette to the cranial aspect of T4's vertebral body.

Providing clinicians with a precise description of how to accurately measure L, S[13] and T4-T8, as well as with the direct standardization formula, would decrease the variability affecting the quantification of the VHS value and would offer reliable results. These could potentially be obtained even more quickly when using digital radiography equipment and a digital version of the formula.

FOOTNOTES

a. Microsoft ® Office Powerpoint 2007 (©Microsoft Corporation, USA)

b. Screen Calipers 4.0, Iconico, NY

c. SAS ® System v9.1.3 software package (SAS Institute Inc, Cary, NC, USA.)

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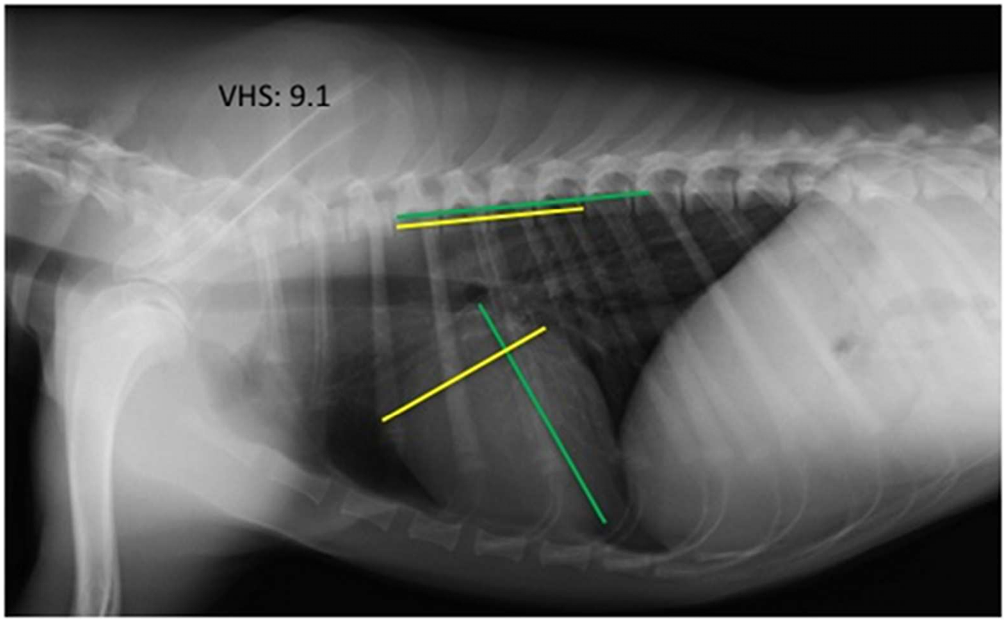

Fig. 1.Right laterolateral thoracic radiograph. Buchanan Vertebral Heart Scale (Buchanan VHS), long (green line) and short (yellow line) cardiac axes are shown. VHS is expressed as total units of vertebral length: 9.1v after repositioning these measurements over the thoracic vertebrae beginning at the cranial edge of T4's vertebral body.
98x61mm (300 x 300 DPI)

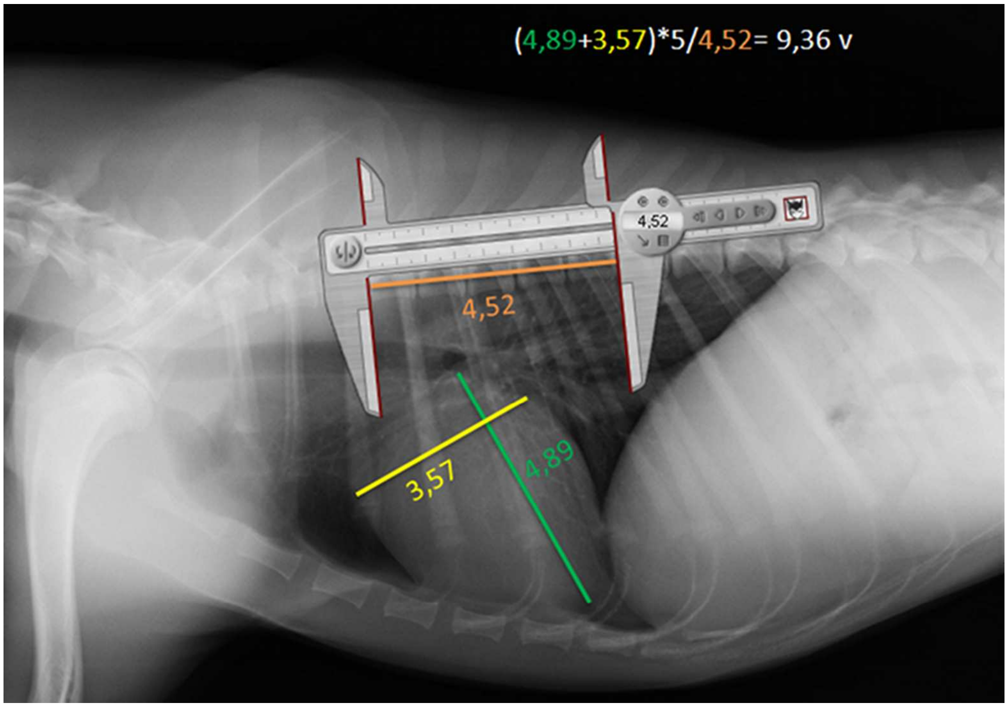

Fig. 2. Right laterolateral thoracic radiograph. Objective Vertebral Heart Scale (Objective VHS), long (green line), short (yellow line) cardiac axes and T4-T8 distance (orange line) are shown (4,89 cm, 3,57 cm and 4,52 cm respectively). Screen caliper is shown measuring T4-T8 distance in cm. VHS is expressed as total units of vertebral length after direct standardization: 9.36v.
111x78mm (300 x 300 DPI)

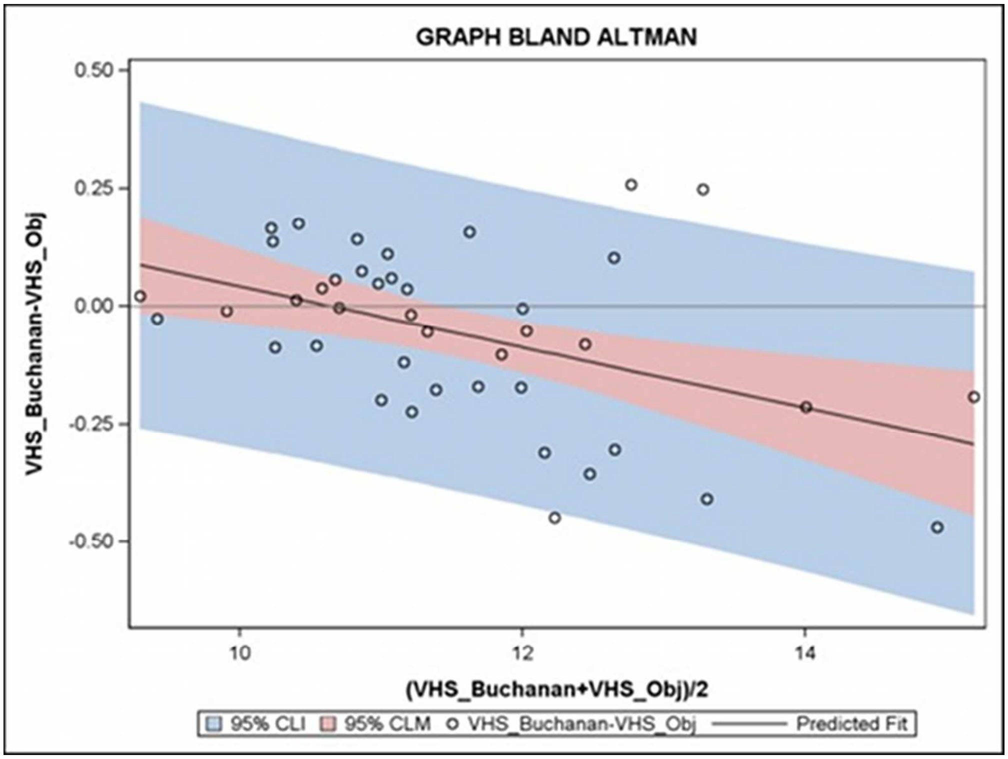

Fig. 3.Bland Altman, this graph shows that Buchanan VHS gives lower values than Objective VHS. However, the differences between the two methods do not exceed 0.5 units.
120x90mm (300 x 300 DPI)

Table 1. *Validity Assessment of Objective and Buchanan VHS (n=9).*

Variable		Variance Components		
	Mean	Population	Inter-Observer	Intra-Observer
objvhs	11.50	0.256	0.011	0.072
Buchvhs	11.35	0.222	0.001	0.086

objvhs: Objective VHS, Buchvhs: Buchanan VHS.