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Equation for Predicting Inferior Vena Cava Diameter as a Potential Pointer for Heart Failure Diagnoses among Adult in Azare, Bauchi State, Nigeria

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Abstract

Background: Dilatation of the Inferior Vena Cava (IVC) is used as the ultrasonic diagnostic feature in patients suspected of congestive heart failure. The IVC diameter has being reported to vary among the various Body Mass Indexes (BMI) and Body Shape Indexes (ABSI). Knowledge of these variations is useful in precision diagnoses of CHF by imaging scientists.

Aim: The study aimed to establish an equation for predicting the ultrasonic mean diameter of the IVC among the various BMI/ABSI of inhabitants of Azare, Bauchi State-Nigeria.

Methodology: Two hundred physically healthy adult subjects of both sexes were classified into under; normal, over and obese weights using their BMIs after selection using a structured questionnaire following their informed consent for abdominal ultrasound scan. The probe was placed on the mid line of the body, half-way between the xiphoid process and the umbilicus with the marker on the probe directed towards the patient`s head to obtain a longitudinal view of the IVC. The maximum IVC diameter was measured from the subcostal view using the electronic calliper of the scan machine. The mean value of each group was obtained and results were analysed.

Results: A novel equation {(IVC Diameter = 1.04 +0.01(X) where X= BMI} has been generated for determining the IVC diameter among the populace.

Conclusion: An equation for predicting the IVC diameter from an individual BMI values in apparently healthy subjects has been established.

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Introduction

The anthropometrics commonly used in health care include Body Mass Index (BMI) and Waist Circumference (WC), which is an indicator of the degree of obesity, estimated with height and weight and it is known to be correlated with the risk of premature death as well as diseases such as CCF [1].

However, both BMI and WC have their limitations in medical practices [2]. In some Asian population, a study conducted among normal subjects in Karachi, the largest city in Pakistan, reveals that body mass index is reliable parameters to consider for avoiding false positive diagnosis of hepatomegaly, heart failure and portal hypertension on a sonogram [3]. Nutritional status and Body Surface Area (BSA) have been reported to affect the dimension of the IVC and the intrahepatic vascular channels [3].

Congestive cardiac failure is a global pandemic with an estimated twenty six million (26 Million) people reported to be affected world- wide [4]. CCF is a pathological condition occasioned by volume overload of the heart mainly due to ischemic and non ischemic factors leading poor venous return and consequently, dilatation of the IVC [4].

Dilatation of the Inferior Vena Cava (IVC) is used as the ultrasonic diagnostic feature in patients suspected of congestive heart failure [5]. The IVC diameter has being reported to vary among the various Body Mass Indexes (BMI). Knowledge of these variations is useful in precision diagnoses of CHF by imaging scientists. In ultrasound technique, the anatomical structures of focus in diagnosing CCF are the intra hepatic vascular channels such as the portal vein and the hepatic portal artery [6]. A diallated Inferior Venae Cavae (IVC) whose luminal diameter is unstable due to pattern of breathing, intra thoracic pressure variations and the extent of diaphragmatic excursion among individuals is also a prominent land mark in CCF diagnoses [6].

Ultrasound scanning machine is useful in the evaluation of porto-systemic diseases like congestive cardiac failure [7]. In ultrasound examination, the anatomical structure of focus in diagnosing patients queried of heart failure is the inferior vena cava [4]. This assertion is deduced from the fact that, homoeostasis could also be maintained in the body because of the close relationship between the inferior vena cava, portal vein and the liver [8]. The use of ultrasound to accurately diagnose some critical pathological condition, such as porto systemic diseases like congestive cardiac failure often puzzles sonographers especially amateurs in the field and as such, they require great care, confidence among other factors in the use and manipulation of equipment apart from having a thorough knowledge and understanding of the anatomy of the portal and related vessels and it`s pathophysiology in other to make reasonably accurate diagnoses of congestive cardiac failure [9].This study therefore, investigates the potential use of BMI in association with ultrasonic IVC diameter to generate an equation for predicting an indication of CCF among the inhabitants of Azare, Bauchi State, Nigeria. Knowledge of this equation will serve as a reference or an alternative measure to lean on in challenges that may arise in the course of taken the ultrasonic IVC diameter to diagnose CCF.

Materials and methods

The materials used for the study include the following:

Sono-crown ultrasound machine, 3.5MHZ of linear probe (transducer), gel, sono-printer, weighing scale, tape rule and a stadiometer and questionnaires

Sample Size

A cross sectional survey was done using systemic random sampling technique whereby the sample size of the research was determined using Yamane equation (indicated below: $ny = \frac{N}{(1+Ne^2)}$ [10] .Where ny is sample size, N is Population size; e is alpha level = 0.05 (If confidence interval is 95% or 0.95).

According to the National Population commission (2020), the population of Azare, Bauchi was estimated at 411,700. From the above formula, the sample size was calculated and the value of three hundred and ninety nine (399) was obtained.

Study location

Figure 1: Insert in the Nigerian map is the geographical site of Azare, Bauchi, State.

Azare is locatedin katagum, Bauchi, Nigeria. It`s geographical coordinates are 110 40` 42`` North, 100 11` 31`` East (Maplandia.com) (Figure 1).

Sonographer/Ultrasound unit

The ultrasound unit of Shifa`a Medical Centre, General Hospital and Federal Medical Centre all of Azare, Bauchi State were used for the study and the measurements were taken alongside with a certified and competent sonographer or a radiologist between April to December, 2020

Inclusion criteria

- All persons between the ages of 18 and 77 years and apparently healthy
- All persons without CCF (normal or healthy subjects)

Exclusion criteria

- All persons below the age of 18 years and above 77 years
- All persons with known hepatobilliary diseases like splenomegally, history of cholecystectomy or cardiac Operation.
- All persons diagnosed of CCF that are either on treatment or not.
- All pregnant women.
- All persons with obvious anatomical defect

Patient and methods

A randomly selective prospective study was carried out at Shifa`a Medical Centre, General Hospital and Federal Medical Centre all in Azare, Bauchi State between March to December, 2020 following the approval of the ethical committee of the Ahmadu Bello University Zaria. Two hundred (200) non-CCF subjects comprising males and females subjects, aged between eighteen and seventy-seven were randomly selected and requested to respond to the questionnaires rule out exclusion indices. They were subjected to abdomino-pelvic ultrasonography for assessment of the Inferior Venae Cava (IVC) diameter in both inspirational and expiratory phases.

Experimental procedures

Positioning and probe selection

Each subject was placed in a supine position and was encouraged to fast overnight in order to decrease the amount of bowel gas which may obscure the target structures. Male subjects were requested to put off their tops while female subjects were required to raise their tops, up to the sub coastal margin. The abdomen preset was clicked on the ultrasound machine which is the recommended interphase for examining abdominal structures. A low frequency probe (3.5 MHZ), that is, curvilinear transducer was used with an ultrasound gel applied on it.

Land marks of Inferior Vena Cava (IVC)

The probe was placed on the mid line of the body, half-way between the xiphoid process and the umbilicus with the marker on the probe directed towards the patient`s right side to obtain a transverse view. At this level, the IVC and the abdominal aorta was seen as elliptical and circular anechoic structures anterior to the vertebral body respectively. The gain on the machine was adjusted to get the best possible image. The IVC appears as an elliptical or “tear drop” structure on the right side of the patients mid line while the aorta appears on the left side. The IVC appears compressible under gentle pressure and not as pulsatile as the aorta. The IVC shows a change in diameter during inspiration and on sneezing while the aorta remains adamant to these factors. The probe was rotated longitudinally in clockwise direction to ninety degrees with the marker on the probe directed towards the head of the patient to obtain the longitudinal axis of the IVC. The long axis of the IVC was seen clearly below the xiphoid process with a branch of the hepatic vein draining into it. As shown below (Figure 2).

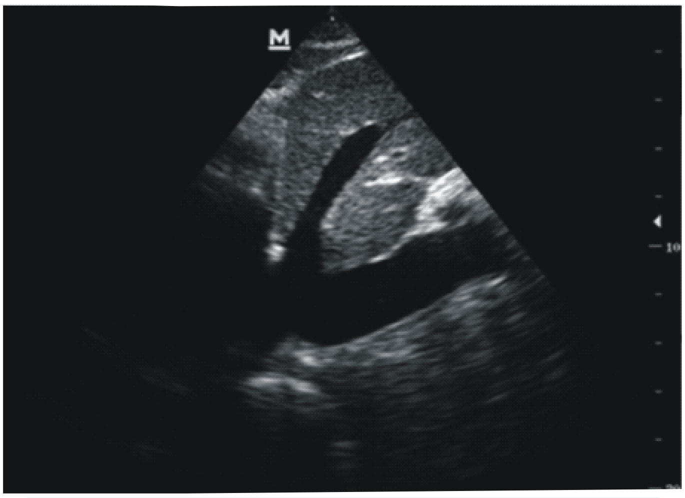

Figure 2: Distended IVC in long axis view [11].

The maximum IVC diameter was measured from the subcostal view with the IVC displayed along its long axis in accordance with the method of Lang et al., and Kawata et al., [11,12]. The diameter was measured immediately caudal to the junction of the hepatic vein with the IVC and approximately 1-2 cm caudal to the junction of the IVC and the ostium of the right atrium as shown in (Figure 3a, b and 4).

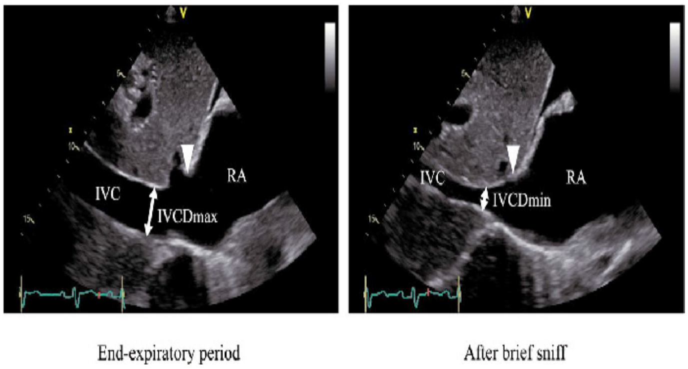

Figure 3 a&b: Example of IVC ultrasound in the subcostal long axis view: Arrowhead indicates the IVC-RA junction. IVC: Inferior Vena Cava; RA: right atrium [11].

Figure 4 a&b: Image of the Inferior Vena Cava (Transverse view) old male obtained for inferior vena cava diameter ement from an ultrasonographic scan of the subject in Plate V Arrow indicates Anterior-Posterior (AP) diameter of the IVC.

Measurement of body mass index

The height and weight of each subject were measured and the BMI(s) were determined using Quetelets’ formula, that is; $BMI=\frac{Weight(kg)}{Height^2}$ as described by Garabed [13].

Height

Height was determined using a height stadiometre. The subject or individual was asked to stand straight against a stadiometre; touching the stand with heels, buttocks and back. The head was oriented in Frankfurt plane (the upper body of the ear opening, the lower body of the eye socket on a horizontal line) and the heels are brought together. The subject was asked to stretch upward and to take and hold a full breath, the headboard of the stadiometer was lowered until it firmly touched the vertex of the head and the height was taken as described by Ayo et al., [14] and Mike et al.,[15].

Weight

The subjects were dispossessed all weighty items on their cloths and asked to mount on the Centre of weighing scale. The record of the weight was taken to the nearest tenth of a kilogram as described by Mike et al., [15].

Blood pressure (BP) measurements

The subject's blood pressures were obtained in accordance with W.H.O guidelines 2021 [16]. Those with blood pressure ranging between 110/90 -120/80 (mm HG) were considered as healthy subjects.

Statistical Analysis

Data obtained were expressed as mean +/- (SEM) standard error of mean, one way Analysis Of Variance (ANOVA) was used to compare the mean difference between and within the groups and the level of significance was set at $p \leq 0.05$ and a 95% confidence interval was applied to the numerical variables which are normally distributed. Statistical analysis was carried out using Statistical Package for Social Science (SPSS) Version 20.

Results

The mean diameter of the inferior vena cava

The mean values of the ultrasonic inferior vena cava diameter among the various body mass index (s) were determined using the equation for simple arithmetic mean.

Relationship between IVC diameter and BMI

A Pearson product-moment correlation was conducted from values derived from Table 1 to examine the relationship between the mean diameter of the Inferior Vena Cava (IVC) and the mean value of Body Mass (BMI) indices in the healthy subjects. Ultrasonic IVC mean diameter in the healthy subjects was positively correlated with the mean value of Body Mass Indices (BMI) of the same subjects; r (198) = (CC) 0.190, $p < 0.01$. A complete list of the correlation is presented in Table 2.

Equation for predicting IVC diameter from BMI

A bivariate regression was conducted to examine how well, the Body Mass Index (BMI) could predict the ultrasonic Inferior Vena Cava diameter (IVC). A scatterplot showed that the relationship between body mass index and ultrasonic inferior vena cava diameter was positive and linear and did not reveal any bivariate outliers. The correlation between BMI and ultrasonic IVC diameter was statistically significant, r (198), CC = 0.190, p < 0.01(Tables 3).The regression equation for predicting ultrasonic IVC diameter from BMI was y = 1.04 +0.01(X), Figure 4.2. The Area under the Curve (AUC) from the receiver Operative Characteristic Curve for this equation was 0.995 (Figure 5a and b) that is, 99.5% of the variance in IVC diameter was predictable from BMI. This is very strong relationship. The bootstrapped 95% confidence interval* for the slope to predict ultrasonic IVC diameter from BMI ranges from 0.03 to 0.021; (Table 4). This means that, for each one-unit increase of BMI, IVC increases by about 0.021 to 0.03 points (Figure 6).

Table 1: Mean Diameter of Ultrasonic Inferior Vena Cava (IVC) And Mean Body Mass Index (BMI) For Pearson Correlation And Regression Analysis.

Variables	Mean(cm)	Std. Deviation	N (Sample Size)
IVC			
Diameter	1.3047	0.3253	200
BMI Types	22.0044	5.17761	200

BMI: Body Mass Index; IVC: Inferior Vena Cava.

Table 2: Correlation Coefficient of Ultrasonic IVC Mean's Diameter and Mean Value of Body Mass Index (BMI) in the Healthy Subjects.

Variables		IVC Diameter	BMI Types
IVC Diameter	Pearson correlation	1	.190**
	Sig. (2- tailed)		0.007
	N	200	200
BMI Types	Pearson correlation	.190**	1
	Sig. (2- tailed)	0.007	

**: Correlation is significant at the 0.01 level (2-tailed) between the various BMI types. r: Degree of Freedom (N-2); CC: Correlation Coefficient (0.190); p: 0.01 (significance value), Note that, each variable correlates with itself at positive 1; BMI: Body Mass Index; IVC: Inferior Vena Cava.

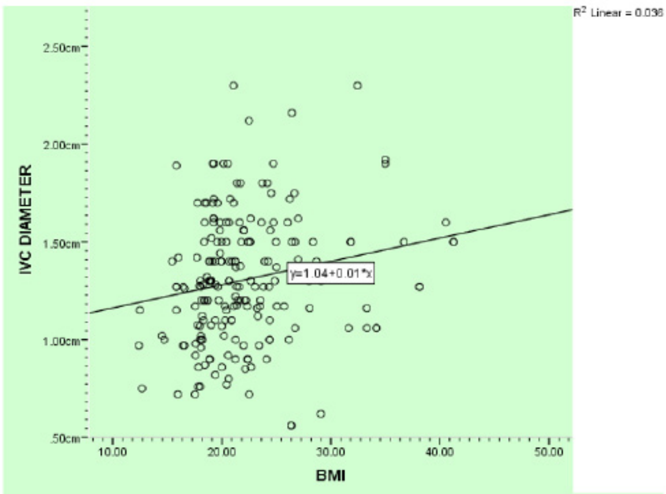

Figure 5: (a) Scatter Plots of the Inferior Vena Cava Diameter and Body Mass Indices; **(b)** Predictive formula of IVC from the mean scatter plots of IVC and BMI scatter plots of inferior vena cava diameter and body mass index.

Table 3: Coefficients of Standardized and Unstandardized Predictor (BMI) and Dependent (IVC) Variables in the Healthy Subjects.

Model		Unstandardized Coefficients	Standardized Coefficients		Sig.
		B	Std. Error	Beta	
1	(Constant)	1.042	0.099		0
	BMI	0.012	0.004	0.19	0.007

1.042: unstandardized coefficient value of the constant "A" (dependent variable); IVC (Todd, 2017).
The table was used in generating the equation for predicting IVC diameter from BMI values.

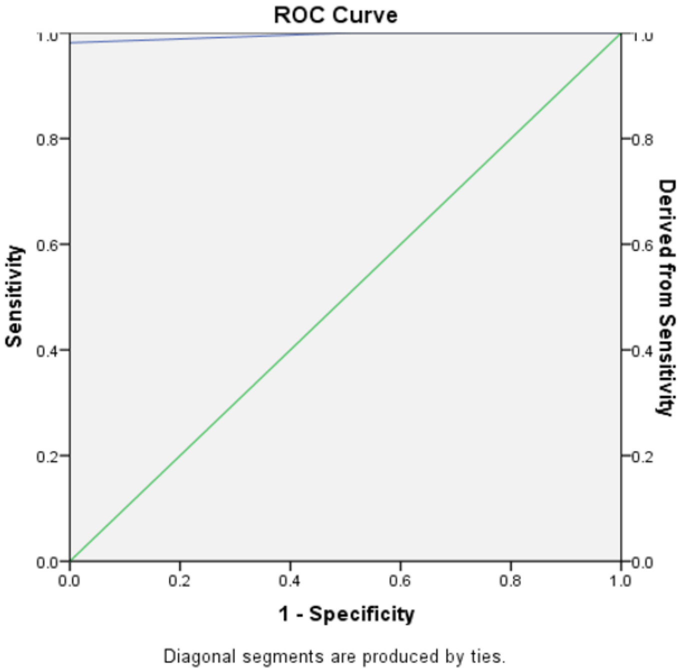

Figure 6: A receiver operative characteristic curve used to evaluate the specificity and sensitivity of the value of the area under the curve.

The receiver operative characteristic curve (ROC)

The test result variable(s): IVCD has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.

a) Under the nonparametric assumption

b) Null hypothesis: True area = 0.5

Model		95.0% Confidence Interval for B	
		Lower Bound	Upper Bound
1	(Constant)	0.846	1.237
	BMI	.003*	.021*

Table 4: Range Of Value of the Slope for Prediction of Inferior Vena Cava (IVC) Diameter from BMI in the Healthy Subjects.

Dependent Variable: IVC sizes, *Denotes ranges of value of slope: 0.03 to 0.021 (In accordance with Todd 2017).

Discussion

Observations made from this study indicated that, the ultrasonic mean diameter of the Inferior Vena Cava (IVC) in all the subjects correlated positively with the mean value of their Body Mass Indexes (BMIs) and an equation for predicting the IVC diameter generated. The observed positive correlation in the IVC diameter with the BMI in the present study was similar with the work of Taniguchi et al.,[3] who reported that the optimal cut-off point of IVC diameter was higher for patients with larger Body Surface Area (BSA) than and much more significantly lower in those with smaller BSA. Since Sunyer had explained that increase in BMI is a function of fat deposition (adiposity) which lent credence to the reason for observed positive correlation between BMI and IVC diameter, it will be logical to see this as the explained probable reason why BMI correlated more with IVC diameter than with ABSI. These findings therefore, indicated that, the higher the Body Mass Index (BMI) of an individual, the wider the ultrasonic IVC diameter of the individual and vice-versa. The sensitivity of the established equations for predicting IVC diameter from BMI in this study was similar with the work of Kawata et al., [12] who reported that the optimal cut-offs maximum values of IVC / Body Surface Area (BSA) for detecting elevated RAP were also estimated for both the larger and the smaller BSA subgroups from respective ROC curves, and level of sensitivity, that is, IVC Class Interval (IVCCI) in both subgroups were approximately forty percent (40%). This means that BMI is a good predictor of IVC diameter and an indicator of congestive heart failure.

Conclusions

An equation for predicting the IVC diameter from an individual BMI values in apparently healthy subjects of Azare, Bauchi State, Nigeria has been established. In emergency situations were the first line medical diagnostic tool and real time bedside ultrasonography are not available to help rule out heart failure, the equation can be useful in the interim when compared with the established cut off values. Knowledge of this equation will serve as a reference or an alternative measure to lean on in challenges that may arise in the course of taken the ultrasonic IVC diameter to diagnose CCF.

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