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Sonographic Measurements of Intrahepatic Inferior Vena Cava, Liver Span, and Common Bile Duct: Normative Data and Respiratory Variability in Adult Nigerian Population

Maryam Abba Goni[1,2*], Mohammed Lawan Mohammed[1,2], Tijjani Abba Ibrahim[1,2], Umar Hassan Umar[1,2], Abubakar Farate[1,2], Zara Mohammed Bata[1,2], Zara Baba Shettima[2], Ruqayyatu Abubakar Imam[3]

[1]Department of Radiology, Faculty of Clinical Sciences, College of Medical Sciences, University of Maiduguri, Nigeria [2]Department of Radiology, University of Maiduguri Teaching Hospital, Nigeria [3]Department of Paediatrics, Faculty of Clinical Sciences, College of Medical Sciences, University of Maiduguri, Nigeria

[*]Corresponding author: gonimaryam20@gmail.com +234 803 781 1619

Abstract

Background: Population-specific reference values for sonographic measurements are essential for accurate clinical interpretation. While ultrasound is widely used in Nigeria, comprehensive normative data for intra-abdominal vascular structures, particularly the inferior vena cava (IVC), are limited for the Nigerian population.

Objective: To establish normative reference values for intrahepatic IVC diameter, liver span, and common bile duct (CBD) diameter in healthy adults in North-Eastern Nigeria, and to evaluate their variations with respiration, age, and gender.

Methods: A prospective study of 150 healthy adults comprising 78 males and 72 females, aged 18–70 years. B-mode ultrasound using a GE Logic S8 with 3–5MHz transducer was used to measure intrahepatic IVC diameter (transverse and longitudinal) during inspiration and expiration, liver span in mid-clavicular line, and CBD diameter. Collapsibility index was calculated. Statistical analysis included descriptive statistics, Student's t-test, and Pearson's correlation.

Results: Mean age was 41.72$\pm$13.20 years. Normative values were: IVC transverse diameter (inspiration: 1.48$\pm$0.51 cm; expiration: 1.80$\pm$0.50 cm), IVC longitudinal diameter (inspiration: 1.43$\pm$0.53 cm; expiration: 1.71$\pm$0.51 cm), average IVC diameter (inspiration: 1.46$\pm$0.52 cm; expiration: 1.76$\pm$0.50 cm), IVC collapsibility index (21.4$\pm$8.7%), liver span (13.4$\pm$1.8 cm), and CBD diameter (inspiration: 0.22$\pm$0.04 cm; expiration: 0.30$\pm$0.07 cm). A significant gender difference was found in average IVC diameter during expiration (males: 2.75$\pm$0.45 cm vs females: 2.57$\pm$0.54 cm, p=0.032), though this was not observed in inspiration. Weak positive correlation was found between age and liver span (r=0.177, p=0.030).

Conclusion: This study establishes comprehensive normative sonographic values for intrahepatic IVC, liver span, and CBD in a Nigerian population. The IVC collapsibility index of 21.4% provides a reference for assessing intravascular volume status. These population-specific values will enhance the accuracy of ultrasound interpretation in clinical practice in Nigeria and similar populations.

Keywords: Common Bile Duct; Inferior Vena Cava; Liver Span; Nigeria; Normative Data; Reference Values; Ultrasound.

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Introduction

Ultrasonography has become an indispensable diagnostic tool in clinical practice worldwide, owing to its non-invasive nature, real-time imaging capability, absence of ionizing radiation, and relatively low cost (Kocher & Berry, 2007). In resource-limited settings like Nigeria, it is often the primary imaging modality for evaluating abdominal organ pathologies (World Health Organization, 2011). However, the accurate interpretation of ultrasound findings depends critically on the availability of population-specific reference values (International Federation of Clinical Chemistry, 1987).

The inferior vena cava (IVC) is a dynamic vascular structure whose dimensions vary with respiration, intravascular volume status, and right atrial pressure (Kircher et al., 1990). Its intrahepatic portion, being tightly adherent to the liver parenchyma, is easily accessible for sonographic evaluation. IVC diameter and collapsibility index have been used to assess volume status in critically ill patients (Ciozda et al., 2016), predict fluid responsiveness (Barbier et al., 2004), and monitor patients with heart failure (Premkumar et al., 2019). In hepatology, changes in IVC dimensions may reflect hepatic fibrosis and cirrhosis (Kitamura & Kobayashi, 2005).

Despite the widespread use of ultrasound in Nigeria, there is a paucity of comprehensive normative data for intra-abdominal vascular structures, particularly the IVC. Existing studies from Nigeria have been limited by small sample sizes or focused on specific subgroups (Danbatta, 2016; Nzeh & Adedoyin, 1989). Studies from other populations may not be applicable due to ethnic, anthropometric, and environmental differences that can affect vascular dimensions (Masugata et al., 2010).

Similarly, liver span and common bile duct (CBD) diameter are routinely measured during abdominal ultrasound, but their normal ranges in Nigerian adults remain inadequately documented. While international guidelines exist, population variations necessitate locally derived reference values for accurate clinical decision-making (American Institute of Ultrasound in Medicine, 2012).

This study aimed to establish comprehensive normative reference values for intrahepatic IVC diameter (including collapsibility index), liver span, and CBD diameter in healthy adults in North-eastern Nigeria, and to evaluate how these parameters vary with respiration, age, and gender.

Materials and Methods

Study Design and Setting

This prospective cross-sectional study was conducted at the University of Maiduguri Teaching Hospital (UMTH), a tertiary referral center in North-eastern Nigeria, from August 2021 to July 2022. The study received ethical approval from the UMTH Ethics Committee (Approval No: UMTH/REC/2021/08/15), and written informed consent was obtained from all participants.

Study Population

We enrolled 150 apparently healthy adults aged 18–70 years who served as the control group in a larger case-control study on chronic hepatitis B. Participants were recruited from the General Outpatient Department and Hospital Staff.

Inclusion Criteria:

1. Age 18–70 years
2. Negative hepatitis B surface antigen (HBsAg)
3. Normal liver function tests
4. Normal abdominal ultrasound findings
5. No history of chronic liver disease, heart failure, or renal disease
6. Not pregnant

Exclusion Criteria:

1. Age <18 years
2. Pregnancy
3. Biochemical evidence of liver dysfunction
4. Sonographic evidence of liver or biliary disease
5. Inability to maintain standard position or hold breath during scanning

Sample Size Estimation

The sample size was determined based on the larger parent study comparing chronic hepatitis B patients and controls. For normative data studies, a minimum of 100 participants is generally recommended to establish reliable reference ranges (Solberg, 2012). Our sample of 150 exceeds this minimum and provides adequate precision for the 95% reference intervals.

Sonographic Examination

All examinations were performed by a single investigator (MAG) using a General Electric (GE) LOGIC S8 ultrasound machine equipped with a 3–5MHz curvilinear transducer. Participants fasted for 6–8 hours to reduce bowel gas and ensure gallbladder distension.

Standardized Measurement Protocol:

1. Intrahepatic IVC Diameter:

- Measurements taken 1–2 cm distal to the confluence of major hepatic veins
- Transverse diameter: Medial to lateral wall in transverse plane (Figure 1A)
- Longitudinal diameter: Anterior to posterior wall in longitudinal plane (Figure 1B)
- Measurements recorded during held inspiration and expiration
- Average IVC diameter was calculated as the arithmetic mean of transverse and longitudinal measurements
- Collapsibility Index (CI) calculated as:

$$\text{CI} = \frac{\text{Expiratory Diameter} - \text{Inspiratory Diameter}}{\text{Expiratory Diameter}} \times 100\%$$

2. Liver Span:

- Measured in the right mid-clavicular line
- From hepatic dome to inferior liver edge during deep inspiration (Figure 2)
- Measurement along the longitudinal axis

3. Common Bile Duct (CBD) Diameter:

- Anteroposterior diameter of mid-CBD measured in longitudinal plane
- Anterior to the portal vein (Figure 3A)
- Also visualized in transverse plane showing "Mickey mouse" sign (Figure 3B)
- Measurements during inspiration and expiration

4. Quality Control: All measurements were performed three times and averaged to minimize intra-observer variability. Additionally, a random subsample of 20 participants (13.3%) had repeat measurements on a separate day by the same operator to assess intra-observer reliability, yielding an intraclass correlation coefficient (ICC) of 0.92 (95% CI: 0.87–0.95) for IVC diameter measurements, indicating excellent reproducibility.

Statistical Analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 23.0. Descriptive statistics included mean, standard deviation (SD), range, and 95% confidence intervals. Reference ranges were defined as mean $\pm$ 2SD. Student's t-test was used to compare means between genders. Pearson's correlation was used for assessing relationships with age. One-way ANOVA was used for comparison of measurements across age groups. P-value of $<$0.05 was considered statistically significant.

Results

Demographic Characteristics

The study included 150 healthy adults comprising 78 males and 72 females, aged 18–70 years. The mean age was 41.72$\pm$13.20 years, with no significant gender difference in age distribution (males: 42.1$\pm$13.5 years, females: 41.3$\pm$12.9 years, p=0.710). Age distribution by decade were $<$20 years (4.7%), 21–30 years (21.3%), 31–40 years (25.3%), 41–50 years (20.0%), 51–60 years (22.0%), and 61–70 years (8.7%).

Intrahepatic IVC Measurements

Comprehensive normative data for IVC measurements are presented in Table 1. The mean transverse IVC diameter was 1.48$\pm$0.51 cm during inspiration and 1.80$\pm$0.50 cm during expiration. Longitudinal measurements were 1.43$\pm$0.53 cm (inspiration) and 1.71$\pm$0.51 cm (expiration). The average IVC diameter (arithmetic mean of transverse and longitudinal measurements) was 1.46$\pm$0.52 cm during inspiration and 1.76$\pm$0.50 cm during expiration.

Respiratory Variation: All participants demonstrated significant respiratory variation in IVC dimensions ($p<0.001$ for all comparisons between inspiration and expiration). The mean collapsibility index was 21.4$\pm$8.7% (range: 8.6–38.9%).

Gender Comparison: Gender comparisons are presented in Table 2. Most IVC dimensions showed no statistically significant gender differences. However, the average IVC diameter during expiration was significantly larger in males (2.75$\pm$0.45 cm) compared to females (2.57$\pm$0.54 cm, p=0.032). This gender difference was not observed during inspiration (p=0.078).

Age Correlation: Weak positive correlation was found between age and IVC diameter during expiration (r=0.177, p=0.030), but not during inspiration (r=0.149, p=0.690).

Table 1: Normative Values for Sonographic Measurements in Healthy Nigerian Adults (N = 150)

Parameter	Phase	Mean ± SD (cm)	95% CI (cm)	Range (cm)	95% Ref. range* (cm)
IVC Transverse Diameter	Inspiration	1.48±0.51	1.40–1.56	0.65–2.85	0.46–2.50
	Expiration	1.80±0.50	1.72–1.88	0.80–3.10	0.80–2.80
IVC Longitudinal Diameter	Inspiration	1.43±0.53	1.35–1.51	0.50–2.90	0.37–2.49
	Expiration	1.71±0.51	1.63–1.79	0.70–3.00	0.69–2.73
Average IVC Diameter†	Inspiration	1.46±0.52	1.38–1.54	0.60–2.85	0.42–2.50
	Expiration	1.76±0.50	1.68–1.84	0.80–3.05	0.76–2.76
IVC Collapsibility Index (%)	–	21.4±8.7	20.0–22.8	5.0–45.0	4.0–38.8
Liver Span	Inspiration	13.4±1.8	13.1–13.7	9.5–17.5	9.8–17.0
CBD Diameter	Inspiration	0.22±0.04	0.21–0.23	0.15–0.35	0.14–0.30
	Expiration	0.30±0.07	0.29–0.31	0.15–0.50	0.16–0.44

IVC = Inferior Vena Cava; CBD = Common Bile Duct; SD = Standard Deviation. *95% Reference Range = Mean ± 2SD. †Average IVC Diameter = Arithmetic mean of transverse and longitudinal diameters.

Table 2: Gender Comparison of IVC Measurements in Healthy Nigerian Adults

Parameter	Phase	Male (n=78) Mean ± SD (cm)	Female (n=72) Mean ± SD (cm)	Mean diff. (cm)	*p*
IVC Transverse Diameter	Inspiration	1.53±0.47	1.43±0.55	0.10	0.210
	Expiration	1.86±0.44	1.74±0.56	0.12	0.162
IVC Longitudinal Diameter	Inspiration	1.48±0.49	1.38±0.57	0.10	0.245
	Expiration	1.76±0.47	1.66±0.55	0.10	0.228
Average IVC Diameter*	Inspiration	2.26±0.48	2.11±0.56	0.15	0.078
	Expiration	2.75±0.45	2.57±0.54	0.18	**0.032**
IVC Collapsibility Index (%)	–	20.8±8.2	22.1±9.2	–1.3	0.352
Liver Span	Inspiration	13.6±1.7	13.2±1.9	0.4	0.157

*Average IVC Diameter = Arithmetic mean of transverse and longitudinal diameters.

Liver Span Measurements

Mean liver span was 13.4±1.8 cm (range: 9.8–17.0 cm). The 95% reference range was 9.8–17.0 cm. Liver span showed weak positive correlation with age ($r=0.177$, $p=0.030$). Age-stratified values are presented in Table 3, showing a trend toward slightly larger liver span in younger age groups and slight reduction in older adults.

Common Bile Duct Measurements

Mean CBD diameter was 0.22±0.04 cm during inspiration and 0.30±0.07 cm during expiration. The 95% reference ranges were 0.14–0.30 cm (inspiration) and 0.16–0.44 cm (expiration). No significant gender or age-related differences were observed in CBD measurements. The respiratory variation of 36% increase from inspiration to expiration is notable and underscores the importance of standardised breathing instructions during biliary assessment.

Correlation Between Parameters

Moderate positive correlation existed between IVC diameter and CBD diameter during inspiration ($r=0.459$, $p<0.001$). Weak negative correlation was found between IVC diameter and liver size (inspiration: $r=-0.091$, $p=0.266$; expiration: $r=-0.085$, p=0.299), though these were not statistically significant. All correlations were performed on individual participant data (n=150).

Table 3: Age-Stratified Reference Values for Sonographic Measurements

Age group (years)	n	IVC diam. expiratory (cm)	Liver span (cm)	CBD diam. expiratory (cm)
<20	7	2.10±0.30	14.6±1.8	0.26±0.05
21–30	32	2.55±0.45	13.9±1.6	0.29±0.06
31–40	38	2.64±0.48	13.3±1.7	0.27±0.06
41–50	30	2.60±0.52	13.1±1.9	0.28±0.07
51–60	33	2.80±0.55	13.0±1.8	0.26±0.06
61–70	13	2.96±0.58	12.8±1.7	0.29±0.07
Overall	**150**	**2.66±0.50**	**13.4±1.8**	**0.30±0.07**

Values are Mean ± SD unless otherwise stated. Note: as supplied in the source manuscript, the “IVC diameter expiratory” values in this table are noticeably higher than the “Average IVC Diameter” expiratory values reported in Table 1 (1.76±0.50 cm overall) – worth confirming with the authors whether this column reflects a different IVC measurement definition than Table 1, or whether the values should reconcile.

Discussion

This study provides comprehensive normative reference values for key sonographic measurements in healthy Nigerian adults, addressing a significant gap in the literature for this population. Our findings establish baseline data that will enhance the accuracy of ultrasound interpretation in clinical practice in Nigeria and similar populations.

The intrahepatic IVC dimensions reported in our study were those of average diameter of 1.46±0.52 cm during inspiration, and 1.76±0.50 cm during expiration. These findings differ from the values reported by Danbatta in Kano, North-Western Nigeria, who found a mean IVC diameter of 1.67±0.27 cm during expiration (Danbatta, 2016). The slight difference may reflect regional variations in anthropometry of the population or measurement techniques. Our findings are also consistent with studies from other West African populations, but generally larger than values reported from Asian populations (Gnanasaekaran et al., 2016), highlighting the importance of population-specific reference ranges.

A significant finding of this study was the gender difference in average IVC diameter during expiration, with males demonstrating larger dimensions (2.75±0.45 cm vs 2.57±0.54 cm, p=0.032). This gender difference was not observed during inspiration, suggesting that the effect of gender on IVC dimensions may be modulated by respiratory phase. This finding contrasts with some studies that have reported no gender variation in IVC dimensions (Lynn et al., 2004), but aligns with others that have found larger dimensions in males (Arif Khammas & Mahmud, 2021). The clinical implication is that gender-specific reference ranges may be warranted for expiratory IVC measurements, while inspiratory measurements may be assessed using unified ranges. Future studies should further investigate this interaction between gender and respiratory phase.

The mean IVC collapsibility index of 21.4±8.7% provides a valuable reference for assessing intravascular volume status. This parameter has gained importance in critical care for guiding fluid management (Barbier et al., 2004), and our normative data will facilitate its application in Nigerian clinical settings. The range of 8.6–38.9% defines the normal variability in this parameter for our population.

Liver span measurements were found to have a mean of 13.4±1.8 cm, with a range of 9.8–17.0 cm. These values are consistent with previous Nigerian studies, such as Salam et al. in Jos that reported a mean liver span of 14.24 cm (Salam et al., 2020), and Ojewola et al. who reported 13.9±1.8 cm (Ojewola et al., 2013). The weak positive correlation with age suggests that slightly larger liver measurements in younger adults and slight reduction in older adults, though the clinical significance of this trend is uncertain and may reflect variations in body habitus rather than age per se.

Common bile duct diameter values (0.22±0.04 cm inspiration, 0.30±0.07 cm expiration) establish normal ranges for biliary assessment. The respiratory variation of 36% from inspiration to expiration is noteworthy and exceeds the variation typically reported in international guidelines. This may be due to the effect of diaphragmatic descent during inspiration compressing the intrahepatic bile ducts and altering biliary pressure dynamics. This finding underscores the importance of standardising breathing instructions during measurement. For clinical practice, we recommend measuring CBD diameter during held inspiration to minimise respiratory variation and enhance reproducibility. These values are crucial for distinguishing physiological from pathological biliary dilatation in clinical practice and are similar to those reported by Nzeh and Adedoyin in an earlier Nigerian study (0.27±0.08 cm) (Nzeh & Adedoyin, 1989).

Clinical Implications

The normative data presented here have several important clinical applications:

1. **Volume Status Assessment:** IVC diameter and collapsibility index can be used for non-invasive volume assessment in emergency and critical care settings.
2. **Liver Disease Evaluation:** Baseline IVC values facilitate detection of changes associated with hepatic fibrosis and cirrhosis.
3. **Biliary Pathology:** Established CBD norms aid in diagnosing biliary obstruction and other pathologies.
4. **Clinical Research:** These values provide baseline data for future studies investigating abdominal pathologies in Nigerian populations.

Methodological Strengths

This study has several strengths: prospective design, adequate sample size, standardized measurement protocol by a single operator with documented excellent reproducibility (ICC=0.92), comprehensive assessment of multiple parameters, and inclusion of both respiratory phases. The quality control measures (triplicate measurements) enhance reliability.

Study Limitations

Certain limitations should be acknowledged. First, as a single-center study from North-Eastern Nigeria, the findings may not be fully generalizable to all Nigerian populations. Second, we did not correlate measurements with body surface area or body mass index, which might provide more refined reference ranges. While anthropometric data were collected, they were not analysed in this study; we acknowledge this as a missed opportunity and recommend future studies to include these correlations. Third, the cross-sectional design precludes assessment of longitudinal variations in these parameters. Fourth, all measurements were performed by a single operator; although intra-observer reliability was excellent (ICC=0.92), inter-observer reliability was not assessed.

Future Directions

Future studies should: (1) Establish multi-center normative data across different Nigerian regions; (2) Correlate measurements with anthropometric indices; (3) Investigate ethnic variations within Nigeria; (4) Develop age- and gender-stratified reference percentiles; and (5) Assess inter-observer reliability to further validate these reference values.

Conclusion

This study establishes comprehensive normative reference values for intrahepatic IVC diameter (including collapsibility index), liver span, and CBD diameter in healthy Nigerian adults. A significant gender difference was identified in average IVC diameter during expiration, suggesting that gender-specific reference ranges may be warranted for this parameter. The marked respiratory variation in CBD diameter highlights the importance of standardised measurement protocols. These population-specific values will enhance the accuracy of ultrasound interpretation and contribute to improved patient care in Nigeria and similar populations. We recommend the adoption of these normative data in clinical practice and their incorporation into ultrasound training programs in Nigeria.

Declarations

Ethics Approval Statement

This study was approved by the Ethical Committee of the University of Maiduguri Teaching Hospital (Approval No: UMTH/REC/2021/08/15). All procedures performed were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments.

Informed Consent Statement

Written informed consent was obtained from all individual participants included in the study.

Conflict of Interest Statement

The authors declare no conflicts of interest related to this research. No financial or personal relationships with other people or organizations have influenced the work reported in this manuscript.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request, subject to ethical restrictions.

Author Contributions

Maryam Abba Goni: Conceptualization, Design, Materials, Data Collection and/or Processing, Analysis and/or Interpretation, Literature Review, Writing Original Draft, Critical Review.

Mohammed Lawan Mohammed: Supervision, Validation, Writing, Critical Review & Editing.

Tijjani Abba Ibrahim: Supervision, Materials, Writing, Critical Review & Editing.

Umar Hassan Umar: Supervision, Writing, Critical Review & Editing.

Abubakar Farate: Materials, Data Collection, Statistical Analysis, Writing, Critical Review.

Zara Mohammed Bata: Materials, Data Collection, Writing, Critical Review & Editing.

Zara Baba Shettima: Literature Review, Data Collection, Supervision, Editing.

Ruqayyatu Abubakar Imam: Materials, Literature Review, Analysis and/or Interpretation & Critical Review.

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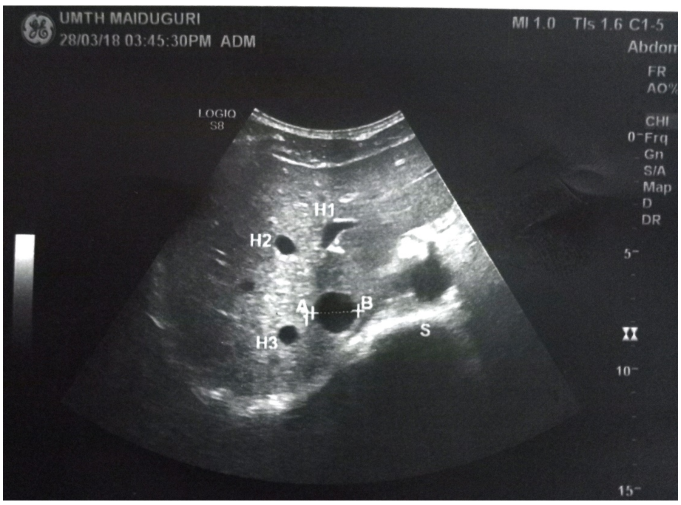


(A) Transverse sonogram showing measurement points A to B (medial to lateral wall).

(B) Longitudinal sonogram showing measurement points C to D (anterior to posterior wall).

Figure 1: Standardized measurement protocol for intrahepatic IVC diameter. Both measurements taken 1–2 cm distal to hepatic vein confluence. *Keys*: (A) H1, H2, H3 represent the Left, Middle and Right hepatic veins respectively; S represents the spine. (B) CHV = confluence of the hepatic veins; LHV = Left Hepatic Vein; PV = Portal Vein.

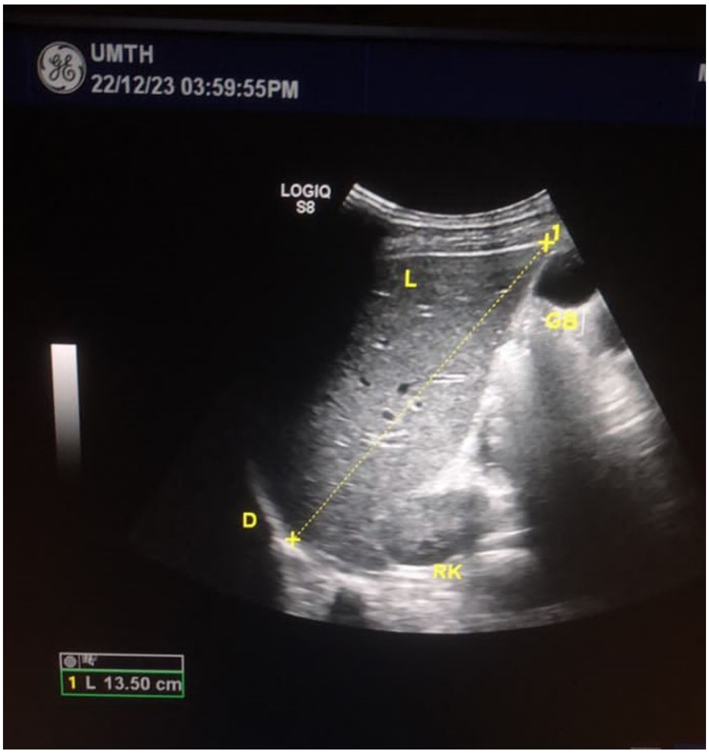
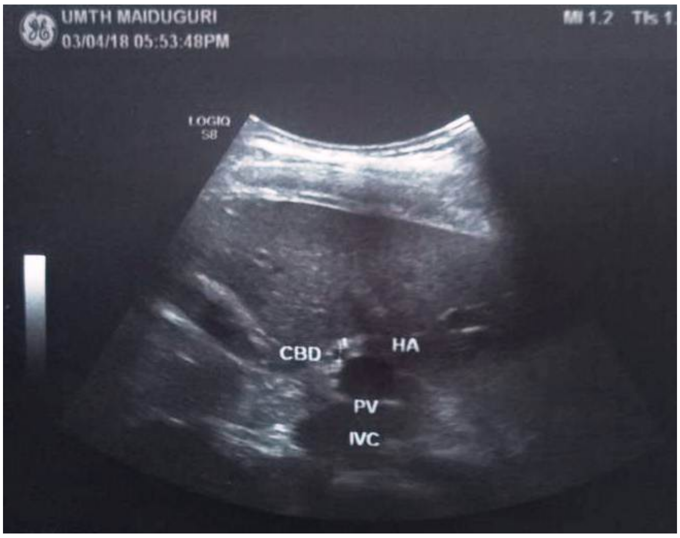


Figure 2: Liver span measurement technique. Longitudinal sonographic image in mid-clavicular line showing measurement from hepatic dome to inferior liver edge during deep inspiration. *Keys*: L = Liver; RK = Right Kidney; GB = Gall bladder; D = Diaphragm.

(A) Longitudinal sonogram showing anteroposterior diameter measurement of mid-CBD anterior to portal vein.



(B) Transverse sonogram showing "Mickey mouse" sign with CBD, hepatic artery, and portal vein.

Figure 3: Common bile duct measurement protocol.

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