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Original Research Article

Establishing normal gallbladder volume: a comparative study of dual-energy computed tomography and ultrasound measurements in a North Indian population

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ABSTRACT

Background: The gallbladder, a critical component of the biliary system, plays a vital role in bile storage and digestion. Dysfunction in the gallbladder often results in gallstone formation, leading to significant healthcare burdens worldwide. Gallstone disease and gallbladder carcinoma are major health concerns, particularly in regions like India, where prevalence is high and poorly understood.
Methods: This study aims to establish the normal baseline volume of the gallbladder using dual-energy computed tomography (DECT) and compare it with measurements obtained via ultrasound (USG). The cross-sectional study conducted at Era's Lucknow medical college and hospital involved 265 individuals aged 18-80 years with non-gallbladder-related abdominal conditions.
Results: Final results showed the mean gallbladder volume to be 29.33±8.70 cm^3 by DECT and 27.40±8.58 cm^3 by USG, with DECT measurements being on average 1.93 cm^3 higher. A significant association was found between gallbladder volume and obesity, but not gender.
Conclusions: The findings suggest DECT provides slightly higher and potentially more accurate measurements of gallbladder volume compared to USG. These insights contribute to a better understanding of gallbladder physiology and the implications of its volume in various pathologies, emphasizing the need for further studies with larger sample sizes to validate these observations.

Keywords: Gallbladder, DECT, USG, Gallstone disease, Gallbladder volume, Obesity, Abdominal imaging

INTRODUCTION

The gallbladder is a small, hollow organ resembling the size and shape of a pear. It forms part of the biliary system, also referred to as the biliary tree or biliary tract. The biliary system consists of a network of ducts within the liver, gallbladder, and pancreas that lead to the small intestine. This system includes both intrahepatic (within the liver) and extrahepatic (outside the liver) components. The gallbladder, specifically an extrahepatic component, functions to store and concentrate bile. Bile, a fluid produced by the liver, is crucial for the digestion of fats, the excretion of cholesterol, and also exhibits antimicrobial properties. Situated in the right upper quadrant of the abdomen, the gallbladder nestles under the liver within the gallbladder fossa. It connects to the remainder of the extrahepatic biliary system through the cystic duct. The liver continuously produces bile, which is then drained into the gallbladder and stored until it is required for digestion.[1]

Dysfunction in the physiology of the gallbladder most commonly results in the production of gallstones. Imbalances in the constituents of bile and biliary sludge secondary to gallbladder hypokinesis can lead to the precipitation of insoluble stones.[2] When these gallstones cause physical blockages in the biliary tree and beyond, pain, inflammation, and infection can result in damage to the gallbladder and a host of other organs.[3] Many gallbladder pathologies will ultimately warrant surgical intervention, and thus cholecystectomy, or removal of the gallbladder, is one of the most common surgical procedures performed in modern times.[4]

Though, in modern times, gallstone disease is often associated with major affliction, the knowledge of gallstones for humans' dates back to the Egyptian civilization dating back to 1000 BC.[5] Gallstones are becoming increasingly common and can be seen in all age groups, but the incidence increases with age; and about a quarter of women over 60 years will develop them[6]. In most cases, they do not cause symptoms, and only 10% and 20% will eventually become symptomatic within 5 years and 20 years of diagnosis. Thus, the average risk of developing symptomatic disease is low, and approaches 2.0-2.6% per year.[7]

In recent years, gallstone disease has become a leading cause of hospital admissions for gastrointestinal problems and is one of the costliest digestive diseases for healthcare system, and is the most common cause of death from non-malignant disease of GI tract.[8] Annual burden of gallstone diseases in US is $6.2 billion, which includes direct and indirect costs of disease.[9]

In India too, the gallstone disease is relatively common with an overall prevalence in the order of 10-20 per cent and predominantly a female disease.[10] There also exists a clear North-South divide (commoner in the North) in the burden of gallbladder diseases in India, a phenomenon which is poorly understood.[11,12] A great deal of effort has been devoted to defining the pathophysiologic basis of gallstone formation, while the epidemiology of gallstone disease has received little attention.[13] Contemporary efforts have evaluated the association of various risk factors for the formation of gallstones and reported an increased risk of gallstones with age in all ethnic groups and geographical conditions.[14,15] Moreover, the prevalence of gallbladder disease is higher in women above 50 years of age (25% to 30%) as compared to young women (5% to 8%).[16] In men, the prevalence also increases with age, but the increase in risk begins much later in life.[17] In India, the prevalence of gallstone disease is more in females than males, and in Northern Indians than Southern Indians followed by Maharashtra (particularly from the coastal region).[18]

Another important problem associated with the gallbladder is that of gallbladder carcinoma, which is a notoriously lethal malignancy. It is the most common malignancy of the biliary tract, representing 80%-95% of biliary tract cancers worldwide, according to autopsy studies.[19] According to cancer statistics, nearly 11,420 new cases of gallbladder carcinoma were treated in the United States of America in 2016, making it the fifth commonest malignancy of the gastrointestinal tract and the most common cancer of the biliary tract.[20]

Another aspect of the problem is that there seems to be a high degree of variance in the distribution of this carcinoma, geographically. The incidence is lower in the Western world, including the USA, UK, Canada, Australia, and New Zealand, compared to Chile, Bolivia, and Israel, where it is more frequent.[21] For India, the national average incidence of carcinoma gall bladder ranges from 0.1 to 3.7 per 100,000 in males and 0.3 to 8.9 per 100,000 in females.[22] But the actual number may be much higher in the endemic zones of Eastern Uttar Pradesh, Bihar, and north-eastern states where it is the third commonest malignancy of the gastrointestinal tract; the reported age-adjusted incidence rates at a population based cancer registry center in northern India, being as high as 5.3 cases per 100,000 population in men and 11.8 cases per 100,000 in women.[22]

Imaging of the gallbladder has an essential role in the examination of patients who present with abdominal pain, especially pain localized to the right upper quadrant. One of the most common methods for imaging the gallbladder is USG and can be employed for initial evaluation of the gallbladder. On the other hand, sonography is highly sensitive and specific for cholelithiasis, detecting >95% for stones over 2 mm.[23] Gallstones are classically mobile and strongly echogenic with marked posterior acoustic shadowing.[24]

CT sensitivity for the detection of gallstones is much less than sonography, typically about 75%-80% for stones ≥5 mm.[25] Calcium containing stones are well seen, even as small as 2 mm; however, pure cholesterol stones may be iso- or even hypoattenuating to bile, decreasing detection rates. Considering this finding, attempts have been made to characterize stones based on density.[26]

However, with the advancement of technology, iterations in imaging techniques have resulted in new findings related to gallbladder and imaging it using different modalities. One of the most commonly reported modality is the gallbladder volume, which has been reported to be inversely associated with the presence of gallstones and other diseases of the gallbladder.[27]

At such, gallbladder has been under constant evaluation to define the baseline volume and correlate it with gallbladder diseases. The present study was planned with the similar goal of defining the normal baseline volume of gallbladder in healthy patients presenting with non-gallbladder-related abdominal diseases and to compare volume of gallbladder measured by DECT and USG.[28]

This study aims to address a significant gap in our understanding of the normal baseline volume of the gallbladder. By utilizing DECT and comparing it with USG measurements, this research intends to establish more accurate benchmarks for gallbladder volume. The findings will provide valuable insights into gallbladder physiology and its implications in various pathologies, contributing to better healthcare outcomes, particularly in regions with a high prevalence of gallbladder diseases.

METHODS

Study type and location

This cross-sectional study was conducted in the department of radiodiagnosis at Era's Lucknow medical college and hospital, Lucknow.

Study period

The research was carried out over a period of 24 months, from March 2021 to December 2023.

Inclusion criteria

The study included subjects aged between 18 and 80 years attending the radiodiagnosis department for DECT and USG with abdominal diseases that did not involve gallbladder pathologies.

Exclusion criteria

Subjects were excluded from the study if they had gallbladder anomalies or pathologies, were pregnant women, were children below 18 years, or had a history of cholecystectomy or hepatobiliary surgery.

Procedure

Ultrasonography (USG) is a non-invasive imaging technique that uses high-frequency sound waves to create images of internal organs. It is widely used to measure gallbladder volume due to its accuracy, safety, and ease of use. The ellipsoid formula, 0.523 × length × width × height, was employed to estimate the gallbladder volumes in fasting and postprandial states.

Ethical approval

The study protocol was approved by the institutional ethics committee of Era's Lucknow medical college and hospital. (Approval number: ELMC and H /RCELL, EC/2021/154), and informed consent was obtained from all the patients.

Statistical analysis

The data were input into Microsoft excel and analyzed using the statistical package for social science (SPSS) software for Windows, version 15.0 (SPSS Inc., USA). Descriptive statistics, including measures of central tendency and dispersion, were applied to the gallbladder dimensions and wall thickness. These measurements were also analyzed in relation to age, sex, height, body mass index (BMI), and body surface area (BSA). Comparisons between data sets were conducted using the student's t test.

RESULTS

The present study was conducted to study the normal gall bladder volume range using DECT and compared it to that of USG. For this purpose, 265 healthy individuals undergoing abdominal USG and DECT scan were enrolled in the study.

Majority of the patients in the study were aged between 21 and 50 years (63%), followed by 51-80 years (33.2%) and ≤20 years (3.8%).

Male preponderance was found in the study population, with males constituting 54% of population, while remaining female (46.0%) gender ratio (M:F) 1.17:1.

Height of patients ranged between 1.25 and 1.85 m. Mean height was 1.61±0.14 meters. Weight of the patients ranged between 34.0 and 95.0 kg. Mean weight was 65.26±15.57 kgs. BMI of patients ranged between 14.03 and 46.87 kg/m^2. Mean BMI was 25.78±6.01 kg/m^2.

Table 1: Distribution of study population according to Gall bladder measurement on DECT.

Parameters	Mean	SD	Min.	Max.
Volume in low energy mode (cm^3)	28.92	8.69	11.40	44.32
Volume in high energy mode (cm^3)	29.74	8.73	12.19	45.20
Mean volume (cm^3)	29.33	8.70	11.93	44.74

Table 1 shows the distribution of gallbladder volume measurements using DECT in both low and high energy modes. The mean volume in low energy mode was 28.92±8.69 cm^3, with a range from 11.40 to 44.32 cm^3. In high energy mode, the mean volume was slightly higher at 29.74±8.73 cm^3, with a range from 12.19 to 45.20 cm^3. The overall mean volume was 29.33±8.70 cm^3, ranging from 11.93 to 44.74 cm^3.

Table 2: Distribution of study population according to gall bladder measurement on USG.

Parameters	Mean	SD	Min.	Max.
Length (cm)	5.02	0.95	3.0	6.9
Depth (cm)	3.21	1.35	1.4	23.0
Width (cm)	1.75	0.35	1.00	2.90
Volume (cm^3)	27.40	8.58	11.20	49.80

Table 2 summarizes the measurements of the gallbladder based on USG imaging. The mean length of the gallbladder was 5.02±0.95 cm, with a minimum of 3.0 cm and a maximum of 6.9 cm. The mean depth was 3.21±1.35 cm, with values ranging from 1.4 cm to 23.0 cm. The width measured 1.75±0.35 cm on average, ranging from 1.00 cm to 2.90 cm. The volume of the gallbladder based on USG was found to be 27.40±8.58 cm^3, with a range from 11.20 to 49.80 cm^3.

Normative range values for GB volume as measured by DECT ranged through 21.55-34.82 cm^3 at ≤20 years of age to 15.06-42.49 cm^3 at 70-80 years of age. Normative ranges showed overlapping, at ages, however the median GB volume was different among different age groups.

Table 3 presents the association of gallbladder volume with nutritional status, categorized as underweight, normal-weighted, overweight, and obese. For USG measurements, underweight individuals had a mean GB volume of 20.64±7.11 cm^3, while normal-weighted, overweight, and obese individuals had mean volumes of 26.08±8.19 cm^3, 26.04±8.96 cm^3, and 29.17±7.75 cm^3, respectively. The ANOVA test indicated a significant association between nutritional status and gallbladder volume measured by USG (f=8.200, p<0.001).

For DECT measurements, underweight individuals had a mean GB volume of 22.08±7.48 cm^3, while normal-weighted, overweight, and obese individuals had mean volumes of 27.86±8.13 cm^3, 28.78±9.27 cm^3, and 30.82±7.45 cm^3, respectively. The ANOVA test also indicated a significant association between nutritional status and gallbladder volume measured by DECT (f=8.472, p<0.001).

The association of gallbladder volume with gender. Based on USG measurements, females had a mean GB volume of 29.40±8.30 cm^3, while males had a mean GB volume of 29.27±9.06 cm^3. The student's t test showed no significant difference between genders (t=0.121, p=0.904).

Similarly, for DECT measurements, females had a mean GB volume of 27.53±8.06 cm^3, while males had a mean volume of 27.28±9.03 cm^3. The student's t test again showed no significant difference between genders (t=0.242, p=0.809).

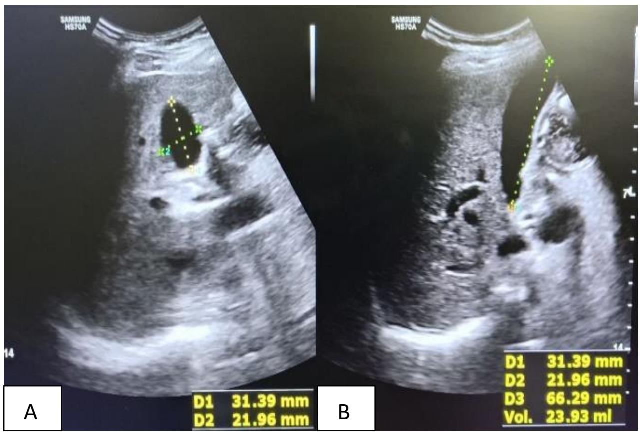

Figure 1 (A and B): USG of gall bladder volume calculated as 23.93 ml.

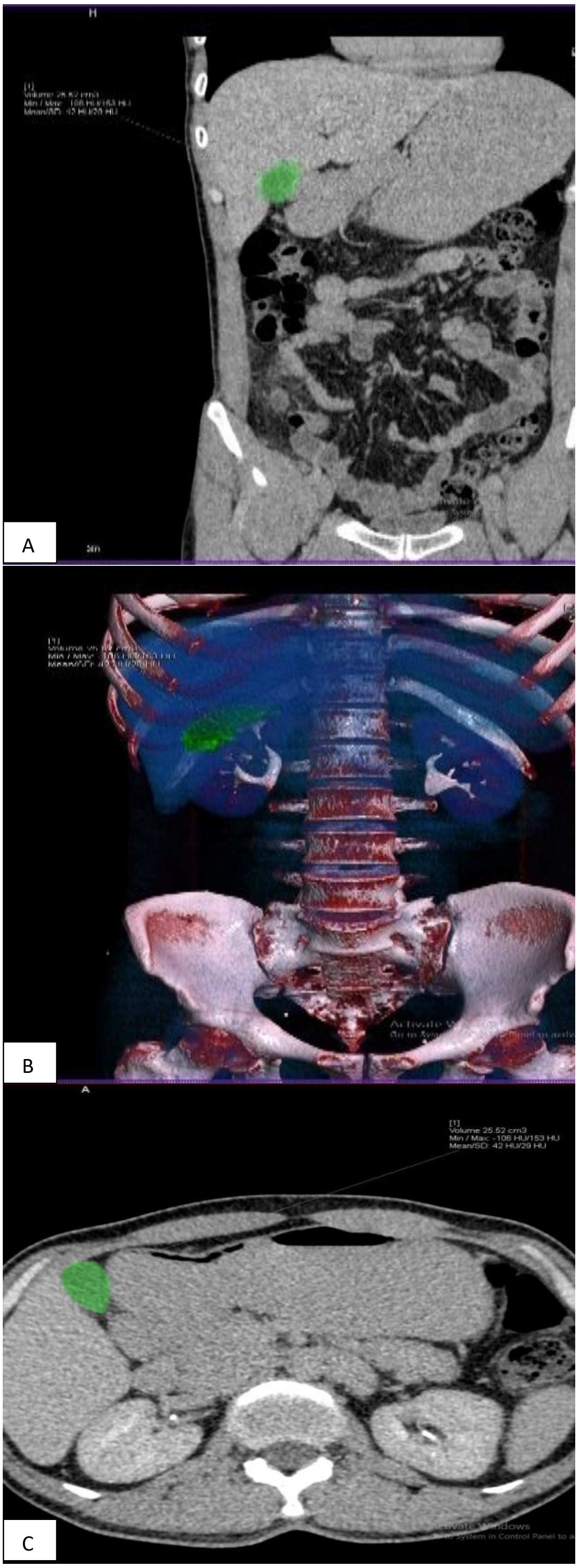

Figure 2 (A-C): CECT of axial view, coronal view and volume rendering technique shows the volume of gall bladder measured by DECT is 25.52 ml in the same patient.

Table 3: Association of gall bladder volume with nutritional status.

Modality	Underweight			Norm- weighted			Overweight			Obese			ANOVA	
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	F	P
USG	25	20.64	7.11	68	26.08	8.19	43	26.04	8.96	68	29.17	7.75	8.200	<0.001
DECT (mean)	25	22.08	7.48	68	27.86	8.13	43	28.78	9.27	68	30.82	7.45	8.472	<0.001

Table 4: Association of gall bladder volume with gender.

Modality	Female		Male		Student's t test	
	Mean	SD	Mean	SD	T	P
USG	29.40	8.30	29.27	9.06	0.121	0.904
DECT (mean)	27.53	8.06	27.28	9.03	0.242	0.809

DISCUSSION

In the present study, the mean age of the cases was 42.64±15.82 years, ranging from 18 to 80 years. A majority of the cases were male (54.0%), with a gender ratio of 1.17. The study was conducted at a tertiary center in the most populated state in India, and included individuals who did not have any abdominal disease based on USG and DECT examinations.

The demographics of the study reflect the characteristics of the Indian population, which has a youthful demographic with a median age of 28 years. Approximately 65% of the population is below 35 years of age. The proportion of children aged 0-6 years is 9.2% (male: 9.4%, female: 8.9%), while the working-age population (15-64 years) constitutes 65.9% (male: 67.4%, female: 64.4%) of the total population. The elderly population (above 65 years) is relatively small, accounting for only 5.5% (male: 5.3%, female: 5.7%) of the total population. However, the elderly population is projected to increase in the coming years due to improved healthcare facilities and increased life expectancy.

The gender distribution reported in the present study is also very similar to the estimates of the last census data and recent national statistical estimates. India has a male-female sex ratio of 929 females per 1000 males, which has shown a slight improvement from previous decade. However, there are significant variations in sex ratio among states, with some states reporting ratios as low as 877 females per 1000 males. Proportion of females in the total population is 48.5% (male: 51.5%, female: 48.5%).

In a study conducted by Chavva and Karpur, the GB weight, height, and width were found to be 6.19±1.09 cm, 2.58±0.58 cm, and 2.82±0.59 cm, respectively, leading to a calculated GB volume of 26.8±12.8 cm^3.[29] This value is similar to present study, but slightly lower, which can be attributed to younger population included in their study.

In the present study, the GB volume calculated by DECT was on average 1.93 cm^3 higher than the GB volume measured by USG. Despite the limited studies regarding GB volume using CT, the present study's findings for GB volume using DECT are similar to the USG findings, albeit slightly higher. This discrepancy can be attributed to DECT technology, which allows for 3D imaging of the object and better discrimination of dense objects due to different energy modes. Hence, it is suggested that GB volume measured by DECT may be more accurate compared to USG. However, DECT is a rather expensive modality and has inherent disadvantages such as radiation risk, making it unsuitable for individuals with implants or conditions that increase radiation risk.

The present study observed a statistically significant association between obesity and increasing GB volume for volumes calculated by both USG and DECT. No statistically significant association was found between gender and GB volume. For cases ≤20 years, the normal GB volume ranged between 21.55 cm^3 and 34.82 cm^3, while for those aged 70-80 years, the GB volume ranged between 15.06 cm^3 and 42.49 cm^3. These findings are similar to those reported by Chavva and Karpur, Ewunonu et al and Adeyekun and Ukadike, who also found that GB volume did not associate with gender or age in their study populations.[29-31]

The findings of this study highlight the importance of understanding GB volume's role in overall health and various comorbidities. The establishment of a normal range for GB volume indicates that GB volume changes with age and is associated with obesity.

Limitations

This study has several limitations. Firstly, the cross-sectional design prevents the establishment of causal relationships between gallbladder volume and various health conditions. Longitudinal studies would provide a better understanding of how gallbladder volume evolves over time.

Secondly, DECT, while accurate, is costly and poses radiation risks, limiting its utility in routine clinical practice. Participants with implants or high radiation risk were excluded, potentially affecting the study's generalizability. Additionally, the study did not include children under 18, pregnant women, or individuals with gallbladder pathologies, limiting the applicability of the results to these groups.

The sample size was relatively small and centered on a single tertiary care center, which may not fully represent the diverse Indian population. Furthermore, the study relied on standardized formulas for estimating gallbladder volume, which may not be accurate for all individuals.

Lastly, while the study found a significant association between obesity and gallbladder volume, it did not explore other potential factors, such as hormonal or neural influences, which could provide a more comprehensive understanding of gallbladder physiology.

In conclusion, further research with larger, more diverse populations and additional factors is necessary to validate these findings and explore the mechanisms regulating gallbladder volume.

CONCLUSION

The present study conducted at the department of radiodiagnosis aimed to establish the normal gall bladder volume range using DECT and compare it to that obtained via USG. This study provides important insights into gallbladder volume measurements in an Indian population using DECT and USG. The findings indicate the average gallbladder volume as measured by DECT (29.33±8.70 cm^3) is slightly higher than that measured by USG (27.40±8.58 cm^3). A significant association was found between gallbladder volume and obesity, but not gender. These findings advance our understanding of gallbladder physiology and highlight the need for further research with larger, more diverse populations to validate these findings and explore additional influencing factors. The study underscores the critical role of gallbladder volume in diagnosing and managing gallbladder-related diseases, emphasizing the importance of accurate measurement methods.

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