ORIGINAL RESEARCH PAPER

Radiodiagnosis

"Ultrasound and Magnetic Resonance Cholangio-Pancreaticography Evaluation of Biliary Stones : Comparative Study"

KEY WORDS: Gall stones, ultrasound & MRCP comparison, biliary duct measurements, extra-hepatic biliary duct dilatation.

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ABSTRACT

Background: Commonest abnormality in gall bladder and bile ducts is stone formation, seen worldwide. Ultrasound (US) is an established primary radiological test for diagnosing biliary stones. Magnetic Resonance Cholangio-Pancreatography (MRCP) with Magnetic Resonance Imaging (MRI) is excellent modality for evaluation of biliary stones, but it has high cost.
Objectives: Objectives were to diagnose stones in gall bladder and extra-hepatic biliary ducts by Ultrasound and to measure extra-hepatic biliary ducts and then, to do MRCP with same fasting status on same day. The findings of US and MRCP were compared.
Materials and Methods: This cross sectional analytical study was done in patients referred for Ultrasound and MRCP to Radiodiagnosis Department, Shree Krishna Hospital, Karamsad and both studies were done consecutively on same day. During 24 months of study, 25 patients were included. USG and MRCP findings and measurements of gall bladder, common bile duct (CBD) and common hepatic duct (CHD) were compared.
Results: Sensitivity of US in diagnosing cholelithiasis and choledocholithias were 100% and 72.7 % respectively as compared to MRCP. Comparison of measurements of common bile duct (CBD) and common hepatic duct (CHD) on Ultrasound and on MRCP by Bland-Altman method for statistical agreement had excellent agreement and moderate agreement respectively.
Conclusion: Ultrasound has high sensitivity and specificity for gall stone and acute calculus cholecystitis, but biliary stones may be missed. Measurements of CBD by US and MRCP have excellent agreement, hence are well comparable.

Background:
Gall stones and biliary stones are commonest condition found in gall bladder and bile ducts in adults, which occur worldwide. According to Stinton LM & Shaffer EA (2012, p. 172) and Wikipedia website (Gall stone, 2017, p. 1), about 80 % of patients with gall stones are asymptomatic with classical symptom of biliary colic pain occurs only in 1–4% of patients. [1,2]. Symptoms may be vague right upper quadrant pain, fever, yellowish skin, vomiting or dark yellowish urine. These patients may present with common complications; which are cholecystitis, pancreatitis and hepatitis. Reshetnyak VI (2012, p.18) and Marschall HU & Einarsson C. (2007, p. 529) have reported prevalence of gall stone disease in western developed world of 10 to 15 % in adults (with about 7.9% in men to 16.6% in women), 4.21% to 11% in Chinese, 3 to 15 % in other Asians and is lowest 3-4% in Africans. [3,4] Kratzer W, Mason RA & Kachele V (1999, p.1) reported similar prevalence on their ultrasound study. [5]

Stinton LM & Shaffer EA (2012, p. 172), Reshetnyak VI (2012, p.18) and Marschall HU & Einarsson C. (2007, p. 529) and Mohamed AW & Solan M (helathline.com, 2017, p.1) have mentioned many risk factors for gall stones; which are 1. Middle age (> 40 Years) 2. Female gender 3. Overweight or obesity 4. High fat, high caloric, low fibre diet 5. On medication having estrogen 6. Diabetes and other metabolic syndrome 7. Liver and intestinal diseases 8. Rapid weight loss 9. Relatives having gall stones and 10. Certain genetic traits and ethnic groups (e.g. 73 % in Pima Indian women and 64.1 % American Indian women have gallstones). [1,3,4,6] Reshetnyak VI (2012, p.18) in his review found increasing evidence that gall stone formation may probably be genetically determined. The risk of gall stone is 2 to 4 times higher in individuals, whose relatives have it. [3] In cases of familial gall stone disease, genetic factors play an overwhelming role with autosomal dominant inheritance.

Types and pathogenesis of Gall stones:
According to Marschall HU & Einarsson C. study (2007, p. 529); about 80–90% of gallstones have cholesterol, either pure cholesterol stone (70%) or mixed stone having additionally bile pigments, calcium salts and glycoproteins. For the formation of cholesterol gall stones, three major mechanisms are: (i) cholesterol supersaturation of bile (ii) gallbladder hypomotility, and (iii) kinetic pro-nucleating protein factors. Pure pigment stones occur in about 10 -15 percent. Brown pigment stones (5-10%) are having about 50% bilirubin and are associated with biliary tract infections (bacterial and helminthic) or abnormal biliary anatomy like Caroli's disease. They are more common in Asia. Black pigment stones (<5%) are composed of calcium bilirubinate with less than 50% bilirubin content and are found in Liver cirrohosis, haemolytic anaemia, ineffective haematopoiesis, Crohn's disease and cystic fibrosis. [4]

Biliary stones usually occur due to migration of gall stones in extra-hepatic: biliary tree. But sometime, they may occur due to marked stasis in common bile duct due to distal stricture.

Ultrasound and M.R.C.P. in diagnosis of gall stone and biliary stones:
Ultrasonography has very high sensitivity for the detection of gall stones; hence it is the most commonly used imaging modality for gall stone disease. On Ultrasonography, gall stones appear as highly reflective echogenic focus within gall bladder lumen having strong posterior acoustic shadow and gravity dependent movement on changing the position of patient. On colour doppler study, it produces "Twinkling" artefact as written by Karosh Khalili & Stephanie R. Wilson (Rumack, 2011, p.202). In acute cholecystitis, hypoechoic thickened gall bladder wall (> 3mm) and fluid in gall bladder fossa are observed. Limitations of ultrasound for extra-hepatic biliary tree evaluation are requirements of lack of gas in overlying bowel and good acoustic window.

According to 2016 World Society of Emergency Surgery (WSES) guideline by Ansaloni L, Pisano M, Coccolini F, Peitzmann AB et. al. (2016, p.1); acute cholecystitis is the complication of gall stone disease having uncertain outcome. No single clinical sign or laboratory test have sufficient diagnostic accuracy to confirm or rule out acute calculus cholecystitis. Abdominal ultrasound is preferred initial imaging modality; because of its low cost, more availability, non-invasive nature and high accuracy for gall stone and diagnostic accuracy of Magnetic Resonance Imaging (MRI) is comparable to abdominal Ultrasound. [8]

On MRI scan and MRCP, gall stones and biliary stones appear hypointense on T2W &STIR images and may have variable signal intensity, appearing hypointense to nearly isointense to gall bladder wall on T1W images. MRI scan and MRCP have

advantages of providing additional information on extra-ductal organal abnormalities, vascular structures, lymph nodes and other liver/pancreatic lesions besides having inherent high contrast resolution and multi-planar capability as metioned by Askar L, Maheshwari S, Pressacco J et. al. (In: Edelman RR, 2006, p. 2483). [9] Reinhold C, Bret C. (1996, p-105) and Hahn PF (In: Stark DD et al, 1999, p. 471) have reported long ago that MRCP can accurately demonstrate common bile duct stones with sensitivity of 81-100%. [10,11] These make MRCP with MRI an examination of choice for diagnosis of biliary tree calculus disease.

Objectives:

1. To diagnose stones in gall bladder and extra-hepatic biliary ducts by Ultrasound and to measure extra-hepatic biliary ducts and then, to do MRCP with same fasting status after US on same day to diagnose stones in gall bladder and extra-hepatic biliary ducts with taking measurements of extra-hepatic biliary ducts.
2. To compare the findings of US and MRCP regarding gall stone and biliary stones as well as to compare diameters of common hepatic duct and supra-hepatic & intra-hepatic parts of common bile duct; which were measured on both modalities.

Materials and Methods:

Adult patients; who had been referred to Radiodiagnosis Department, Shree Krishna Hospital, Karamsad for Ultrasound and MRCP both and diagnosed as having gall stone or biliary stone on ultrasound and were followed by MRCP on same day with same fasting status, were included in this study. Total 25 patients were included in the 24 months duration from February 2013 onwards. Their clinical symptoms, signs, haemogram & hepatic function test were recorded in proforma. Serum amylase and lipase were done, whenever indicated; which were noted.

Ultrasonography of hepato-biliary system was done on GE medical systems, VOLUSON 730 PRO or LOGIQ-E by 3.5-5.0 MHz linear convex transducer with patient in fasting status for at least 8 hours. Colour Doppler mode (if needed) was used to differentiate bile ducts from vessels.

Absolute contra-indications for MRI scan like placement of cardiac pacemaker, ferromagnetic aneurysmal clip, Neuro-muscular stimulator etc. were ruled out by history and recorded in consent form before patient taken in MRI gantry room.

Then, MRI scan of upper abdomen with MRCP was done on Superconductive 1.5 Tesla Magnetom Symphony-Vision Maestro class MRI scan. (Manufacture: Siemens AG Co., Erlangen, Germany). Four element body coil array was used with bed-sheet covering patient's abdomen to prevent direct contact with radio-frequency coil.

Table 1. Protocol for non-contrast MRI scan of abdomen.

Plane	Breath Hold Sequence		Weighted Image	Thickness (mm)	Inter-slice Gap (mm)	Field of view (FOV)	Matrix	NEX
AXIAL	Gradient Echo Sequence (Flip angle 70)		T1W	5-8 mm	2-3 mm	300-350 mm	134 x 256	1
	Turbo Spin Echo (Turbo factor 134)		T2W	5-8 mm	2-3 mm	300-350 mm	134 x 256	1
	Optional	HASTE-STIR (Half-fourier Acquisition Single Shot Turbo Spin Echo-Short TI Inversion Recovery) (Turbo factor 224, TI 150)	T2W	5-8 mm	2-3 mm	300-350 mm	224 x 256	1
		Iru-FISP (Fast Imaging with Steady State Precession) (Flip angle 60)	T2W	5-8 mm	2-3 mm	300-350 mm	146 x 256	1
CORONAL		GRE Iru-FISP (Fast Imaging with Steady State Precession) (Flip angle 60)	T1W	5-7 mm	2-3 mm	300-350 mm	180 x 256	2
		HASTE-STIR (Half Fourier Acquisition Single Shot Turbo Spin Echo-Short TI Inversion Recovery) (Turbo factor 179, TI 150)	T2W	5-7 mm	2-3 mm	300-350 mm	179 x 256	1

Table 2. MRCP Protocol.

	Sequence	Weighted Image	Thickness (mm)	Inter-slice Gap (mm)	Field of view (FOV)	Matrix	NEX
MRCP	HASTE THICK SLAB (Turbo factor 307, GRAPPA- iPAT factor 2)	T2W	40-80 mm	-	280-350 mm	307 x 284	1
	HASTE THIN SLAB (Turbo factor 269, GRAPPA- iPAT factor 2)	T2W	3-5 mm	0	320-350 mm	269 x 384	1
	3D RESTORE (Respiratory Triggered Navigation based) (Turbo factor 121)	Heavily T2W	1.2 mm	0	300-350 mm	241 x 256	1

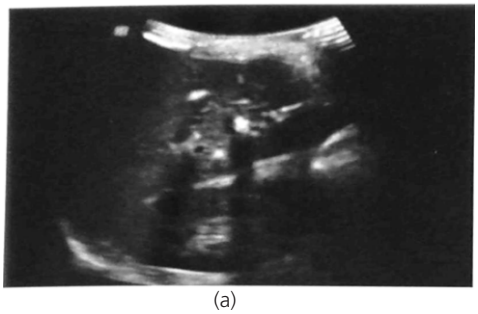
Orally, water with small amount of Gadolinium (negative contrast medium) was given to suppress intra-gastric fluid signals before M.R.C.P. study as and when required.

Results:

Mean age of the patients in this study was 55 years [± 15 yrs (SD)]. Abdominal pain was the commonest symptom with 23 patients having it. Other common symptoms were yellowish discoloration of sclera/urine (12 patients) and nausea/ vomiting with anorexia (6 patients). Raised Alkaline Phosphatase (ALP) level was commonest bio-chemical abnormality and is noted in 14 patients. Serum total bilirubin was raised in 12 patients.

In our study, all cases of gall stones were accurately diagnosed on Ultrasound and MRCP. Out of these 14 patients of gall stones, 4 patients also had acute cholecystitis, Eleven patients had biliary stones as cause of symptoms, among which 2 patient also had gall stones and 1 patient had multiple stones in gall bladder and intrahepatic biliary radicles.

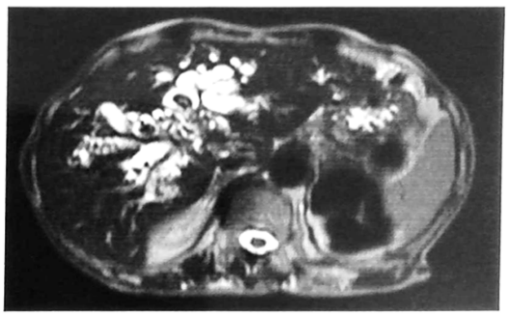
Images of a case of our study having multiple gall stones, CBD stones and intra-hepatic biliary stones are shown below:



(a)

(b)

(c)



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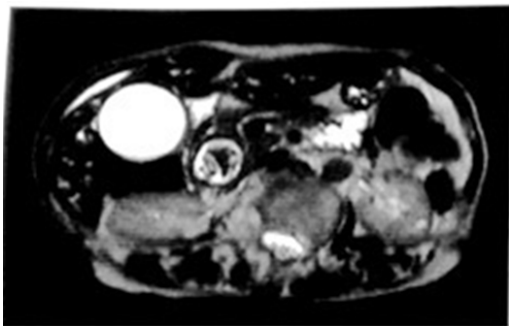

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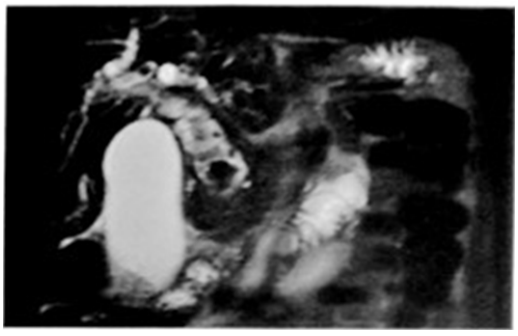

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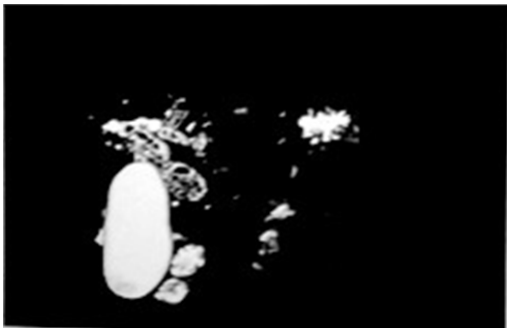

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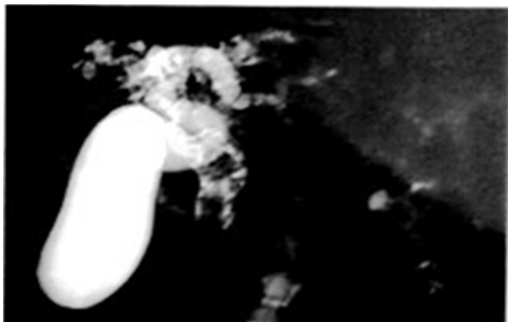


(h)

(a), (b) & (c) Ultrasound Images showing multiple stones. (d) Five mm thick MRI T2W axial image (e) STIR axial image & (f) STIR coronal image, showings multiple stones, MRCP images (g) 4 mm thin oblique coronal image & (h) 45 m thick slab images, showing multiple stones.

On Ultrasound, thickened oedematous gall bladder wall was seen in all 4 patients of acute calculus cholecystitis; while pericholecystic fluid collection was seen in 3 such patients. These findings were also seen on MRCP.

Patients' demographic particulars, Liver Function Test as well as Ultrasound & MRCP findings are tabulated below in table 3.

Table 3. Patients' Demography & Laboratory Data With Ultrasound And MRCP Findings:

Gall Stone and Biliary Stone	USG & MRCP Findings		
	Cholelithiasis [N = 14]	Choledocholithiasis with or without Cholelithiasis [N = 11]	Acute Calculus Cholecystitis [N =4]
Most common age group (yrs)	Commonest Age Group: 55-70 Y	Commonest Age Group: 55-70 Y	Commonest Age Group: 55-60 Y
Gender (Female : Male ratio)	10 F & 4 M (2.50:1)	8 F & 3 M (2.67:1)	3F & 1M (3:1)
Most common symptom	Abdominal pain: 13	Abdominal pain: 10	Abdominal pain & fever : 4, Jaundice: 2
Raised Total S. Bilirubin	7	5	2
Raised S. Bilirubin (Direct > Indirect)	7	5	2
S. ALP level	8	6	4
Dilated IHBR	5	5	2
Diagnosed on US	14	8	4
Biliary Stones not diagnosed on US	None	3	None
Diagnosed on MRCP	14	11	4

Out of 25 cases, intra-pancreatic portion of CBD was not well delineated in 7 cases on ultrasound due to overlying duodenal or pyloric gas shadow. Out of these 7 cases, 2 patients had partially obstructing calculus in lower end of CBD and 1 patient had calculus in proximal portion of cystic duct, which were not observed on ultrasound. Total 3 cases of biliary stones were not diagnosed on Ultrasound, but they were found in MRCP.

The sensitivity and specificity of ultrasound for biliary stone (as compared to MRCP) were 72.7 % and 100 % with accuracy of 86.35 percent. Ultrasound and MRCP had same accuracy of 100 % for gall stones.

Table 4. Measurement of gall bladder volume and extra-hepatic biliary ducts in patients with gall stones and biliary stones.

Measurements of extra-hepatic biliary tree [N = 25]	Ultrasound (Mean ± SD)	MRCP (Mean ± SD)
Right Hepatic Duct (RHD)	4.98 ± 4.15	5.00 ± 4.16
Left Hepatic Duct (LHD)	5.22 ± 3.88	5.37 ± 4.21
Common Hepatic Duct (CHD)	8.75 ± 5.63	9.01 ± 6.00
Supra-pancreatic CBD	10.38 ± 6.00	10.48 ± 5.92
Intra-pancreatic CBD [N = 18]	8.55 ± 5.63	8.46 ± 5.36
Man Gall Bladder Volume (in ml)*	42.70 ±35.59	42.60 ±35.99

***** Gall bladder volume was calculated by Ellipsoid formula; which is as follows:

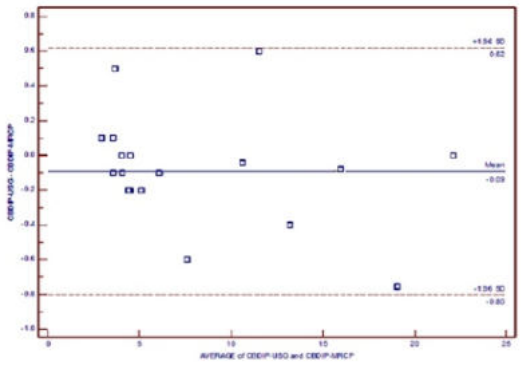
$$\text{Volume} = \frac{(\text{Length} \times \text{width} \times \text{height}) \times \pi}{6}$$

The value of π is taken approximated as 3.142.

Table 5: Comparative agreement analysis of measurements of extra-hepatic biliary tree by Ultrasound & MRCP at various levels by Bland-Altman Method.

Biliary ducts	No. of findings by US and MRCP [N]	Difference Between Mean by US & MRCP	95 % Confidence Limit	
			Upper	Lower
Right Hepatic Duct	25	0.04	-0.54	+0.43
Left Hepatic Duct	25	0.08	-0.80	+0.65
Common Hepatic Duct	25	0.26	-1.30	+ 0.9
Common Bile Duct Supra - Pancreatic (CBD SP)	25	0.08	-0.84	+0.75
Common Bile Duct Intra-Pancreatic (CBD-IP)	17	0.08	- 0.78	+0.64
Gall Bladder Volume	25	1.1	- 26	+ 24.3

Chart 1: Bland-Altman Plotting of comparison of intra pancreatic C.B.D. diameter measurements by USG & MRCP.



Among these patients, 2 patients underwent laproscopic cholecystectomy, 1 patient had abdominal cholecystectomy and 3 patients had ERCP with biliary stenting; so surgical/ERCP correlation were done in 24 % of patients. Other patients were treated with conservative medical treatment and recovered.

Discussion:

Results of the study is compared with study done by Mandelia A, Gupta AK, Verma DK, Sharma S. (2013, p. 1941).

Table 6. Comparison of our study with MandeliaA, Gupta AK et al study (2013) [12]

Gall Stones &/or Biliary Stones	Present study [N = 25]	Mandelia A et al [N= 26]
Most common age group	55-70 years	> 50 years
Gender (Female : Male Ratio)	2.58:1	1.3:1
Most common symptom	Abdominal pain (92% cases)	Abdominal pain (90% cases)
Most common bio-chemical abnormality	Raised ALP levels (61.5% cases)	Raised ALP levels (73.33% cases)
Raised total Serum bilirubin level	56 % cases	33.33% cases
Diagnosed cholelithiasis cases (by USG & MRCP)	All 14 cases (100% cases)	19 out of 21 cases
Cholelithiasis cases not visualised on USG (as compared to MRCP)	None	1 out of 20 cases (95% cases)
Diagnosed choledocholithiasis (by USG)	8 out of 11 cases (72.7 % cases)	23 out of 26 cases (88.5% cases)
Choledocholithiasis cases not visualised on USG (but diagnosed on MRCP)	3 out of 11 cases (33.3% cases)	2 out of 25 cases (8% cases)

Ching-Ruei Hung, Ay-Chiao Huang, Yen-Chen Chen et. al. (2011, p.93) had used single shot thick slab MRCP projection for measurement of CBD diameter and they considered MRCP was easy, precise and non-invasive technique of CBD measurement of bile ducts. [13] They found that proximal CBD is bigger in diameter than distal CBD in diseased group as well as in normal.

They concluded that proximal CBD diameter gave more accurate estimation of true CBD diameter. In our study also, proximal CBD diameter is bigger than distal CBD diameter.

Nai-Chi Chiu & Yi-You Chiou (2012, p. 423) in their editorial article suggested that 3D MRCP approach is better suited for optimum visibility of whole biliary tree as compared to the conventional 2D thick slab sequence. [14] For measurement of CBD diameter, 3D MRCP can also be used.

Boys JA et. al. (2014, p. 432)) had conducted the study on prediction of CBD stones in setting of acute cholecystitis by taking CBD diameter in 248 patients. Measurements of CBD diameter, taken from ultrasound as well as MRCP were evaluated. [15] They observed that, there was no significant difference in mean ultrasound CBD diameter for patients undergoing MRCP with or without confirmed choledocholithiasis (6.2 ± 3.4 v/s 7.4 ± 3.6 mm; p = 0.3; 95% Confidence Interval 3.5 to 1.2), as well as after excluding diagnosed patients of choledocholithiasis using ultrasound.

The limitations of this study were small sample size, inability to establish surgical correlation in all cases. Limitation of measurements taken in this study is 0.01 mm by Ultrasound (approximated to 0.1 mm) and 0.1 mm by ERCP.

Conclusions:

Ultrasound has high accuracy for gall stone; but biliary stones in extra-hepatic biliary ducts may be missed in 27.3 percent. MRCP is highly accurate to diagnose gall stones and biliary stones. There was excellent agreement in measurements of common bile ducts taken by both modalities and so these measurements are comparable with each other. Moderate agreement is noted in common hepatic duct measurement; which make them fairly comparable. The mean gall bladder volume has moderate agreement; but relatively wide variations are noted in the volume measurement.

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