Original Article

Adhesions Detection and Staging Classification for Preoperative Assessment of Difficult Laparoscopic Cholecystectomies: A Prospective Case–Control Study

Atul Kapoor[1]*, Bholla Singh Sidhu[2], Jasdeep Singh[2], Navjot Brar[2], Paramjit Singh[2], Aprajita Kapur[1]

[1]Department of Radiology, Advanced Diagnostics, Amritsar, Punjab, India, [2]Department of Surgery, Parwati Hospital and Sukh Sagar Hospital, Amritsar, Punjab, India

Abstract

Background: Laparoscopic cholecystectomy (LC) is the treatment of choice for cholelithiasis; however, there are procedural difficulties in determining preoperative detection of a difficult LC. The current methods using clinical and sonographic variables to identify difficult LCs have limitations to identify gallbladder adhesions which form the most common cause. We present a new method of evaluation using acoustic radiation force impulse (ARFI)-based virtual touch imaging (VTI) for the detection and classification of these patients. **Methods:** Fifty consecutive patients of cholelithiasis were evaluated preoperatively using conventional scoring system (CSS) and by new adhesion detection and staging (ADS) system, and patients were classified into three classes (I–III) with class I being easy, II and III being moderate-to-high difficulty LCs. Peroperative classification was done based on the difficulty level during surgery after visualization of gallbladder adhesions. The sensitivity, specificity, and area under the curves (AUCs) of both systems were compared. **Results:** Out of 50 patients, 72% and 54% of patients were in class I by CSS and ADS classification, while 28% and 46% were in class II and III, respectively, and were labeled as difficult LC cases; differences being two classifications were statistically significant ($P = 0.02$). Sensitivity, specificity, negative predictive value, and accuracy for ADS were 91%, 100%, 93.1%, and 96.0%, and for CSS, 60.9%, 100%, 75%, and 82% with AUCs of 1.0 and 0.63, respectively. **Conclusion:** ARFI-based VTI accurately detects gallbladder adhesions and can determine the difficult cases of LCs preoperatively using ADS classification and shows higher accuracy than CSS classification, which results in lower operative time and risk of complications.

Keywords: Acoustic radiation force impulse, elastography, laparoscopic cholecystectomy, ultrasonography

Introduction

Laparoscopic cholecystectomy (LC) has become the procedure of choice for the treatment of symptomatic gallbladder disease worldwide.[1] However, the surgeons often experience the dilemma of myriad of difficulties during cholecystectomies chiefly due to the presence of undiagnosed gallbladder adhesions, coexisting congenital anomalies of the biliary system, and the presence of comorbidities.[2] Out of these, pericholecystic adhesions form the most common and the most formidable diagnostic challenge. Even though ultrasonography is the investigation of choice for gallbladder evaluation, there is no ultrasound feature, which can identify a difficult cholecystectomy patient.[3] Lal *et al*.[4] proposed sonographic parameters for predicting difficult cholecystectomies, but suggested these to be combined with clinical parameters. Several studies have been done to predict the difficulty level preoperatively using clinical and sonographic parameters.[5,6] A commonly used classification has been the one by Randhawa and Pujahari[7] to predict the difficulty of gallbladder resection preoperatively with good sensitivity up to 80%. Algorithm by Bouarfa *et al*.[8] also had 83% accuracy in predicting difficult cholecystectomies preoperatively. However, the limitations of all the existing methods have been the lack of ability to directly visualize gallbladder adhesions by existing imaging tools.[9] Hence, all the above studies predict the likelihood of difficult cholecystectomies based on the presence of various coexisting variables. We propose a new system of detection and

Address for correspondence: Dr. Atul Kapoor, Department of Radiology, Advanced Diagnostics, 17/7, Kennedy Avenue, Amritsar, Punjab, India.
E-mail: masatulak@aim.com

Received: 24-04-2022 **Revised:** 09-05-2022 **Accepted:** 02-06-2022 **Available Online:** 10-09-2022

Access this article online

Quick Response Code:

Website: https://journals.lww.com/jmut

DOI: 10.4103/jmu.jmu_36_22

How to cite this article: Kapoor A, Sidhu BS, Singh J, Brar N, Singh P, Kapur A. Adhesions detection and staging classification for preoperative assessment of difficult laparoscopic cholecystectomies: A prospective case–control study. J Med Ultrasound 2023;31:137-43.

classification of gallbladder adhesions preoperatively, which can differentiate difficult gallbladder surgeries from routine cholecystectomies and name it as the "adhesion detection and staging (ADS) differentiate classification to differentiate difficult laparoscopic cholecystectomies."

Patients and Methods

Informed consent was obtained from all prospective patients who presented to us with pain right hypochondrium for routine abdominal sonography over a 6-month period from August 2021 to January 2022. Fifty consecutive patients diagnosed with cholelithiasis who were candidates for laparoscopic cholecystectomies were enrolled in the study. Approval was taken from the institutional review board (AD/abd02/21). Clinical history along with patient demographic data was duly recorded along with history of any prior surgery or endoscopic retrograde cholangiopancreatography procedure. Any patient with a recent acute attack of cholecystitis and pancreatitis were excluded from the study. All examinations were done on the Acuson S2000 system (Siemens, Mountview, California, USA) by experienced sonologists (AK and APK) in a standard prescribed manner. Gallbladder location, distension, size, and number of calculi along with wall thickness were recorded. Visualization of cystic duct, common bile duct, and condition of liver was also recorded. Acoustic radiation force impulse (ARFI) shear wave elastography was done using virtual touch imaging (VTI)-based technique using the same system. The technique involves the use of push ultrasound pulse to create shear waves by displacement of tissues in the region of interest and generate a stiffness/fibrosis map. VTI sample was taken from three gallbladder sites, i.e., fundus, body, and neck region. Pericholecystic and gallbladder wall stiffness was recorded as an image on color at all the three sites. Areas of increased stiffness/fibrosis were visualized as red on color scale with green being no fibrosis for all the three sites and were graded from E1 to E4 for each site for the diagnosis of adhesions [Figures 1, 2 and Table 1]. ADS classification was done for staging based on the findings of the VTI, and all patients were classified into three classes [Table 1].

Based on the clinical and sonographic findings, the patients were classified by conventional scoring system (CSS) classification-modified Randhawa and Pujahari[7] into three classes (I–III) based on their scores [Table 2]. All 50 patients underwent laparoscopic cholecystectomies done by experienced surgeons (BSS, JS, and NB). Peroperative findings were recorded along with the presence of adhesions. Patients were classified as per Zuhlke *et al*.[10] classification into three preoperative classes [Table 3]. Patients in class I by both classifications were deemed as routine cholecystectomies, while class II and class III as difficult surgical cases.

Statistical analysis was done using Analyse-it software (Leeds, UK) for mean, median, and confidence intervals (CIs) of all parametric data, and the results were compared using Student's *t*-test and Mann–Whitney nonparametric tests for statistical significance (P value being set at < 0.05 as significant). Sensitivity and specificity along with receiver operating characteristic analysis were done for the two preoperative scoring methods to compare their ability to predict the difficulty level for preoperative LCs.

Results

The study comprised 50 prospective patients of cholelithiasis who underwent laparoscopic cholecystectomies. The patient demographics are shown in Table 4. Of these, 27 patients were male and 23 were female with a mean age group of 51.1 years. The mean body mass index (BMI) of the study group was 27.8 Kg/m^2. The conventional classification system classified 36 (72%) patients in class I, while 11 (22%) and 3 (6%) were in class II and class III, respectively [Table 5]. ADS classification categorized 27 (54%) patients in class I [Figures 3-5], while 15 (30%) patients in class II [Figures 6-8] and 8 (16%) in class III [Figures 9-14]. On peroperative classification by Zuhlke *et al*., 28 (56%) patients were in class I, while 15 (30%) and 7 (14%) were patients were in class II and class III. A high Pearson's correlation was observed between ADS and CSS and peroperative classifications to stage patients into three difficulty

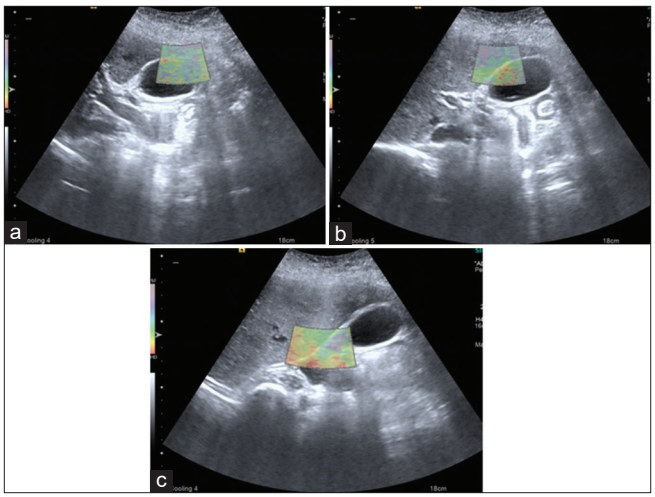

Figure 1: VTI images of gallbladder at three sites (a) fundus, (b) body, and (c) neck with E1 grade adhesions at neck. VTI: Virtual touch imaging

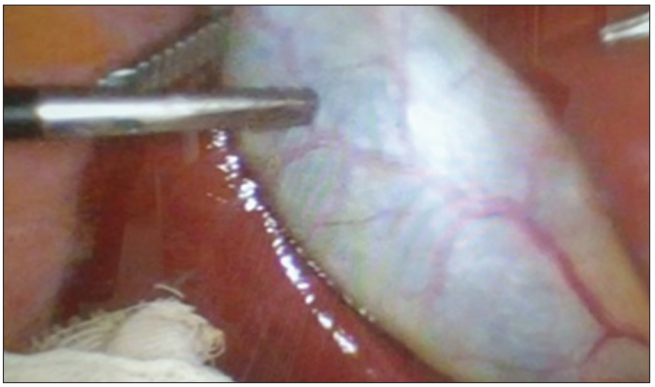

Figure 2: Peroperative view with adhesion free body and fundus of gallbladder

Table 1: Adhesion detection staging scoring system

Serial number	Parameter
Class I	No adhesion/adhesions present (E1-2) one site
Class II	Adhesions present (E2-3) two sites
Class III (A-C)	A. Adhesions present (E2-3) three sites
	or B. Adhesions present (E2-3) two sites with a contracted gallbladder
	or C. Adhesions (E4) any site
Elastographic grades	E1: No adhesion
	E2: Pericholecystic stiffness less than<2 cm
	E3: Pericholecystic stiffness more than>2 cm
	E4: Dense pericholecystic stiffening of any size

Table 2: Conventional scoring system (modified Randhawa)

Parameter	Maximum score
Age	
<60	1
>60	1
History of previous colics present	2
BMI weight (kg/m^2)	
<25	0
25–27.5	1
>27.5	2
Abdominal scar	Infraumblical: 1, supraumblical: 2
Palpable gallbladder	2
Sonographic wall thickness of GB (mm)	
<4	0
>4	2
Pericholecystic collection	1

*Class I: Total score of < 5, Class II: 6–10, Class III: >10. BMI: Body mass index. GB: Gallbladder[7]

Table 3: Peroperative adhesion scoring (Zuhlke)

	Operative time
Class I: No adhesion/minimal adhesions easy to separate	<35 min
Class II: Adhesions easy to separate with blunt dissection	35–60 min
Class III: Adhesiolysis possible with sharp dissection and some damage to underlying organ	>1 h

Table 4: Patient demographics

Parameter	Mean	95% CI
Age (years)	51.1	48.1–54
Sex		
Males	27	
Females	23	
BMI (kg/m^2)	27.8	27.2–28.4
Frequency of colics		
First episode	31	
>1	19	
History of prior ERCP	6	
History of prior surgery	4	
GB wall thickness (mm)	3.5	3.1–3.8

BMI: Body mass index, ERCP: Endoscopic retrograde cholangiopancreatography, GB: Gallbladder, CI: Confidence interval

levels of laparoscopic cholecystectomies [Table 5]. However out of 43% patients were labeled as difficult LC's peroperatively while ADS and CSS labeled 46% and 28% patients as difficult; the differences being statistically significant ($P < 0.001$). A complication rate of 2% was seen in class III patients mainly as postoperative small collections. The median operative times and the hospital stays of the three ADS classes were 35, 55, and 80 min, respectively, while hospital stays were 2, 2.5, and 5.5 days, respectively, the differences being statistically significant by Mann–Whitney U test [Table 6]. The sensitivity and specificity and positive and negative predictive values of CSS classification to detect difficulty levels were 60.9%, 100%, 100%, and 75%, while that of ADS classification were 91.0%, 100%, 100%, and 93.1%, respectively [Table 7], with area under the curves being 63% and 91% [Figure 14], respectively.

Discussion

There have been many studies in the literature,[7,11-16] which have tried to predict difficult LCs preoperatively. In all these studies, indirect clinical and imaging variables were assigned a score. Cases with higher scores than a cutoff value were labeled as difficult LC cases. The goal of identification would be to alert the surgeon for increased time of surgery, as well as increased risk of complications and even conversion to open surgery in such cases. In a series of 6380 by Singh and Ohri,[13] 1466 (22.6%) cases of difficult LC preoperatively were detected and had a conversion rate of 2%. About 18.8% of the cases had dense adhesions in the Calot's triangle, which was seen as the single most important risk factor. This made the dissection difficult and posed risk of injury to surrounding viscera. Conventional imaging has limitations in detecting adhesions till date. Our study used the ARFI elastography technique with VTI to address this problem and computed a classification system to diagnose and stage the extent of adhesions. The present study showed that the use of ADS classification was able to accurately identify gallbladder adhesions on imaging and also staged them for predicting difficulty levels with higher sensitivity and negative predictive values of 91% and 93.1% as compared to 60.1%, and 75% by CSS classification of Randhawa *et al*.[7] while specificity showed no change in both the classifications. In the present study, CSS missed 18% of difficult LCs cases similar to results seen by the study of Singh and Ohri.[13] This resulted in increased operative time and also increased the risk of complications. Lal *et al*.[4] also concluded in their study that adhesions at Calot's triangle were the most common cause of LC conversions into open surgeries. Our study demonstrated that the use of VTI appears as a useful tool in the preoperative workup as it can be combined with routine ultrasonogram

Table 5: Comparison of two scoring systems with peroperative scoring

Class	ADS scoring system (%)	CSS (%)	Peroperative scoring system (%)	Pearson correlation (*r*)	*P*	Complications
Class I	28 (56)	36 (72)	27 (54)	0.97	<0.0001	Nil
Class II	14 (28)	11 (22)	15 (30)	0.96	<0.0001	Nil
Class III	8 (16)	3 (6)	8 (16)	0.82	<0.0001	2%*

*Gallbladder bed collection. Power of correlation test for adhesion detection was 1.00. ADS: Adhesion detection staging, CSS: Conventional scoring system

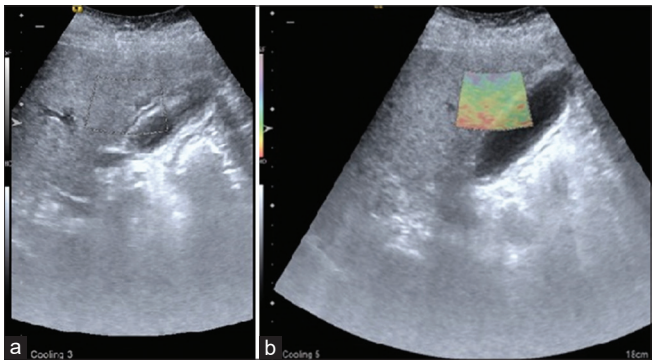

Figure 3: (a) Ultrasound image with gallbladder calculus and sludge with 4.5-mm thick wall. (b) VTI image at fundus with no adhesions with adhesions at the body. VTI: Virtual touch imaging

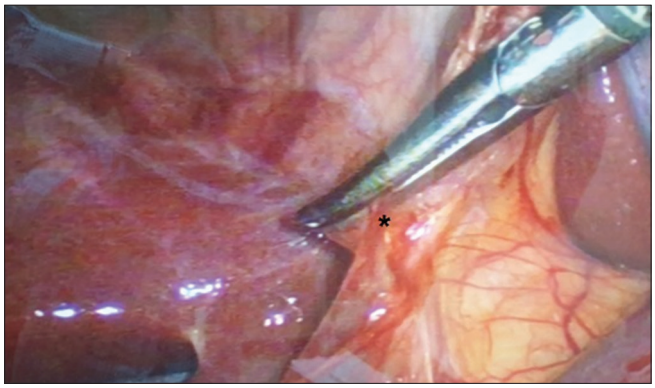

Figure 4: Peroperative view showing adhesions of the body with duodenum (*) with adhesion free fundus

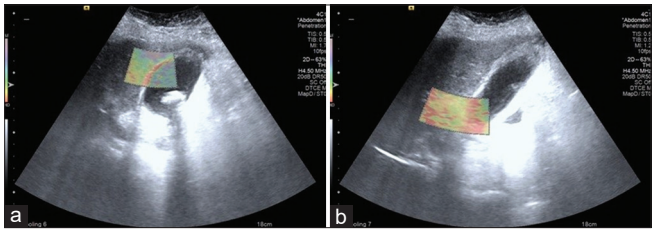

Figure 5: (a) VTI image at body with stiff gallbladder wall (b) E2 adhesions at neck of gallbladder. VTI: Virtual touch imaging

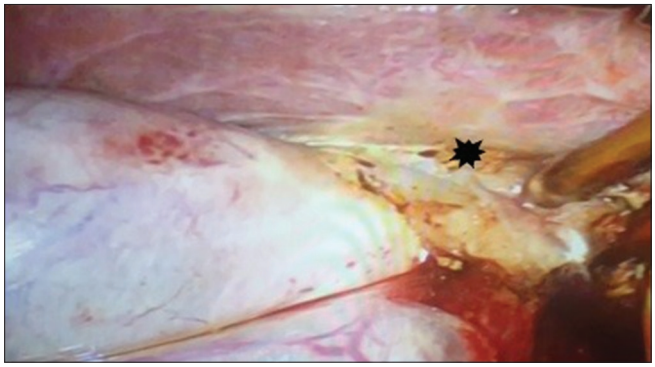

Figure 6: Peroperative image with adhesions at neck(✹)

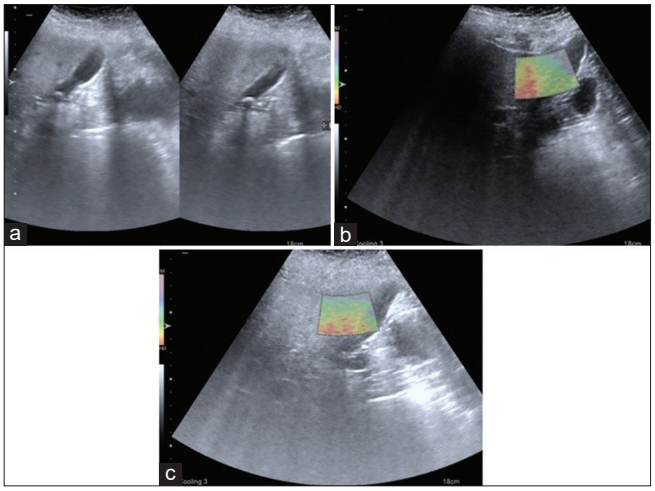

Figure 7: (a) Ultrasound image with gallbladder calculus (b and c) VTI images with adhesions E2 at two sites at body and neck. VTI: Virtual touch imaging

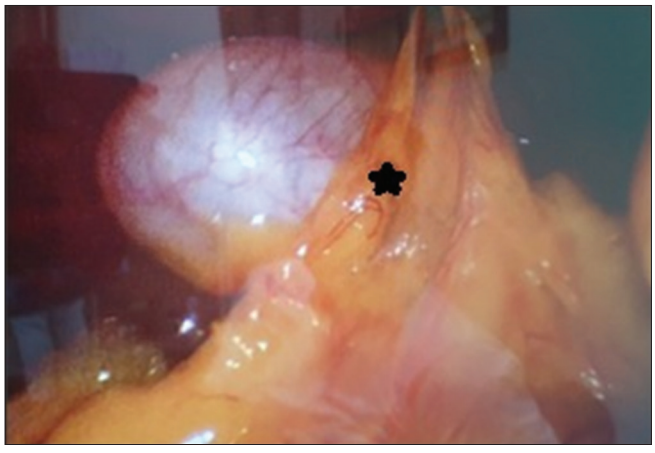

Figure 8: Peroperative image with adherent omentum at body and neck of gallbladder(✹)

in the same sitting and visualizes the adhesions directly as a function of increased tissue stiffness at the three sites of the gallbladder as has been shown in this study. The current study also showed that the sonographic parameter of gallbladder

Table 6: Comparison of operative time and hospital stay by adhesion detection staging classification

ADS class	No of patients (%)	Median operative time (min)	IQR	Interclass *U* statistic	*P*	Median hospital stay (days)	IQR	Interclass *U* statistic	*P*
Class I	28 (56)	35	10	Class I-II/*U* = 389	<0.0001	2.0	0	Class I-II/*U* = 337	<0.0001
Class II	14 (28)	55	20	Class II-III/*U* = 111.5	<0.0001	2.5	0.54	Class II-III/*U* = 224	<0.0001
Class III	8 (16)	80	9.1	Class I-III/*U* = 224	<0.0001	5.5	1.04	Class I-III/*U* = 112	<0.0001

IQR: Interquartile range, ADS: Adhesion detection staging

Table 7: Sensitivity specificity analysis of conventional scoring system and adhesion detection staging classifications

	Difficult lap chole (CSS)			Difficult lap chole (ADS)		
	Abnormal (+)	Normal (−)	Total	Abnormal (+)	Normal (−)	Total
Abnormal (+)	14	0	14	21	0	21
Normal (−)	9	27	36	2	27	29
Total	23	27	50	23	27	50
Sample prevalence	0.460			0.460		
Sensitivity-TP proportion (95%CI)	0.609 (0.385–0.803)			0.913 (0.720–0.989)		
Specificity-TN proportion (95%CI)	1.000 (0.872–1.000)			1.000 (0.872–1.000)		
FP proportion (95%CI)	0.000 (0.000–0.128)			0.000 (0.000–0.128)		
FN proportion (95%CI)	0.391 (0.197–0.615)			0.087 (0.011–0.280)		
Likelihood ratio (+)	+∞			+∞		
Likelihood ratio (−)	0.39			0.09		
At sample prevalence						
Correct classification	0.820 (0.686–0.914)			0.960 (0.863–0.99)		
Misclassification	0.180 (0.086–0.314)			0.040 (0.005–0.137)		
Positive predictive value	1.000 (0.768–1.000)			1.000 (0.839–1.000)		
Negative predictive value	0.750 (0.578–0.879)			0.931 (0.772–0.992)		

CI: Confidence interval, CSS: Conventional scoring system, ADS: Adhesion detection staging, TP: True positive, TN: True negative, FP: False positive, FN: False negative

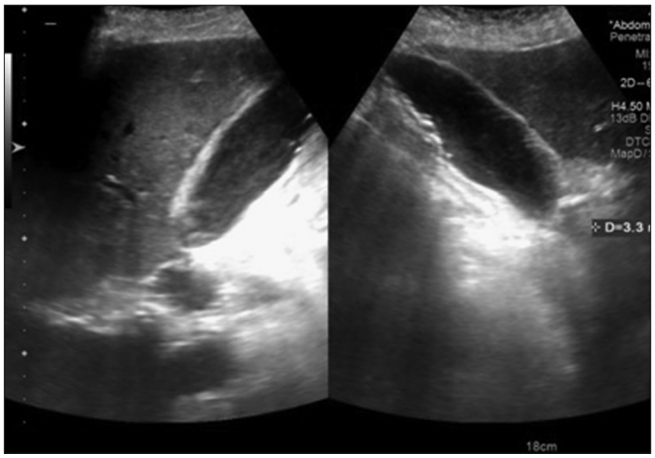

Figure 9: Class III b case showing ultrasound image with microcholelithiasis with 3.3 mm thickened wall

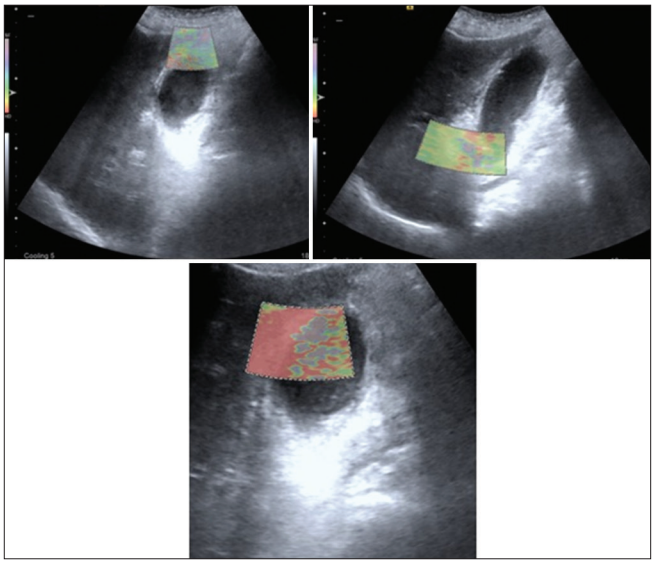

Figure 10: VTI image of same patient with three site adhesions with dense adhesions at body of gallbladder-E4 grade. VTI: Virtual touch imaging

wall thickness was not a very useful predictive variable in class II and class III patients as they had a mean wall thickness of 3.47 mm (2.9–4.4 mm 95% CI). All these cases, hence, would be underscored as 1 as per the CSS and classified as class I cases in the study. This was the likely reason of the lower sensitivity of 60.9% of CSS in our study and also in the study of Randhawa and Pujahari[7] compared to ADS classification which had 91% sensitivity. This was contrary to the studies done by Carmody *et al*.[3] and Gupta *et al*.[11] who showed > 4 mm wall thickening in all difficult cases. The possible reason for the difference with these studies could be that cases with < 4 mm wall thickening were labeled as easy LC in these but had significant adhesions which were

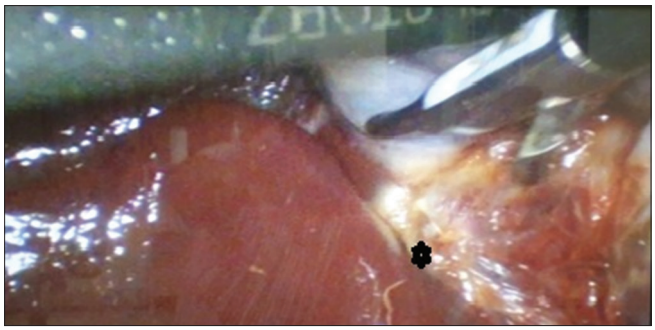

Figure 11: Peroperative view with dense adhesions at body of gallbladder.( )

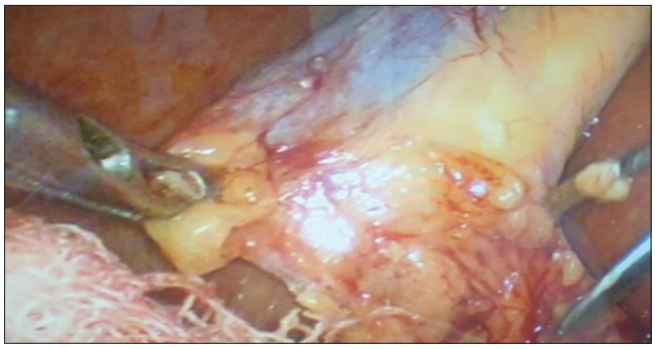

Figure 13: Peroperative image of same patient showing buried adherent gallbladder

undetected. In the present study, even clinical variables used in CSS such as abdominal scars and BMI were not very sensitive parameters to detect difficult LCs. In the present study, abdominal scars were present in only 4/23 patients of difficult LC cases and all patients had above-normal BMI. Boraii and Abdelaziz[17] recently have raised similar questions for the need to revise the current preoperative classifications for predicting difficult LC and the need for new parameters. ARFI-based VTI has been a documented method for evaluating stiffness/fibrosis in many organs such as liver, breast, and thyroid,[18,19] and the results of the current study show that it can play a useful role in identifying difficult LC cases preoperatively.

Conclusion

This is the first study which demonstrates the visualization of pericholecystic adhesions by preoperative imaging and defines a new preoperative ADS classification which can accurately identify difficult LC cases.

Acknowledgment

We acknowledge Gurvinder Singh and Surinder Bir Singh for manuscript preparation and digital archives.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

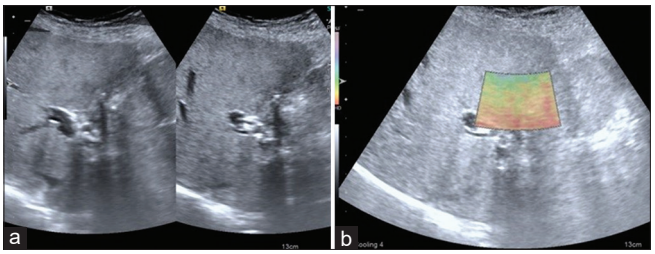

Figure 12: ADS class III c patient (a) Ultrasound image with contracted small gallbladder with calculus (b) E3adhesions seen on VTI image. VTI: Virtual touch imaging

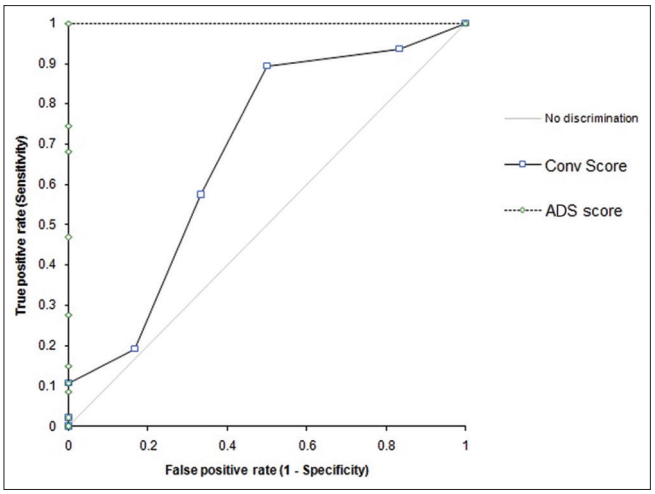

Figure 14: AUC for ADS and CSS classification for difficult LC. AUC: Area under the curve, CSS: Conventional scoring system, LC: Laparoscopic cholecystectomy

References

1. Le VH, Smith DE, Johnson BL. Conversion of laparoscopic to open cholecystectomy in the current era of laparoscopic surgery. Am Surg 2012;78:1392-5.
2. Daradkeh SS, Suwan Z, Abu-Khalaf M. Pre-operative ultrasonography and prediction of technical difficulties during laparoscopic cholecystectomy. World J Surg 1998;22:75-7.
3. Carmody E, Arenson AM, Hanna S. Failed or difficult laparoscopic cholecystectomy: Can preoperative ultrasonography identify potential problems? J Clin Ultrasound 1994;22:391-6.
4. Lal P, Agarwal PN, Malik VK, Chakravarti AL. A difficult laparoscopic cholecystectomy that requires conversion to open procedure can be predicted by preoperative ultrasonography. JSLS 2002;6:59-63.
5. Kama NA, Kologlu M, Doganay M, Reis E, Atli M, Dolapci M. A risk score for conversion from laparoscopic to open cholecystectomy. Am J Surg 2001;181:520-5.
6. Lee NW, Collins J, Britt R, Britt LD. Evaluation of preoperative risk factors for converting laparoscopic to open cholecystectomy. Am Surg 2012;78:831-3.
7. Randhawa JS, Pujahari AK. Preoperative prediction of difficult laparoscopic cholecystectomy: A scoring method. Indian J Surg 2009;71:198-201.
8. Bouarfa L, Schneider A, Feussner H, Navab N, Lemke HU, Jonker PP, *et al.* Prediction of intraoperative complexity from preoperative patient data for laparoscopic cholecystectomy. Artif Intell Med 2011;52:169-76.
9. Rosen M, Brody F, Ponsky J. Predictive factors for conversion of laparoscopic cholecystectomy. Am J Surg 2002;184:254-8.
10. Zuhlke HV, Lorens EM, Straub EM, Savaas U. Pathophysiology used

classification vonadhesionslongerback. Arch Chir Suppl Verh Dtsch Ges Chir 1990;345:1009-16.
11. Gupta N, Ranjan G, Arora MP, Goswami B, Chaudhary P, Kapur A, *et al*. Validation of a scoring system to predict difficult laparoscopic cholecystectomy. Int J Surg 2013;11:1002-6.
12. Vivek MA, Augustine AJ, Rao R. A comprehensive predictive scoring methodfor difficult laparoscopic cholecystectomy. J Minim Access Surg 2014;10:62-7.
13. Singh K, Ohri A. Difficult laparoscopic cholecystectomy: A large series from north India. Indian J Surg 2006;68:205-8.
14. Schäfer M, Krähenbühl L, Büchler MW. Predictive factors for the type of surgery in acute cholecystitis. Am J Surg 2001;182:291-7.
15. Nachnani J, Supe A. Pre-operative prediction of difficult laparoscopic cholecystectomy using clinical and ultrasonographic parameters. Indian J Gastroenterol 2005;24:16-8.
16. Sakuramoto S, Sato S, Okuri T, Sato K, Hiki Y, Kakita A. Preoperative evaluation to predict technical difficulties of laparoscopic cholecystectomy on the basis of histological inflammation findings on resected gallbladder. Am J Surg 2000;179:114-21.
17. Boraii S, Abdelaziz DH. Does difficulty assessment of laparoscopic cholecystectomy using currently available preoperative scores need revision? Egypt J Surg 2020;39:641-6.
18. Zhang YF, He Y, Xu HX, Liu C, Le-Guo H, Liu LN. Virtual touch tissue imaging on acoustic radiation force impulse elastography: A new technique for differential diagnosis between benign and malignant thyroid nodules. J Ultrasound Med 2014;33:585-95.
19. Youk JH, Gweon HM, Son EJ. Shear-wave elastography in breast ultrasonography: The state of the art. Ultrasonography 2017;36:300-9.