Original Article

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Surgery Section

Diagnosis of Acute Appendicitis using Modified Alvarado Score and Abdominal Ultrasound

AABHAS MISHRA[1], SUKUMAR SANTOSH KUMAR[2], ANAMIKA SINHA[3]

ABSTRACT

Introduction: Acute Appendicitis (AA) requires prompt surgery to prevent complications, and the diagnosis is mostly based on clinical features where scoring systems like Modified Alvarado Score (MAS) have been found to be helpful. However, as clinical findings tend to be subjective, Abdominal Ultrasound (AUS) can be used to add some objectivity to the diagnosis of AA.

Aim: The aim of the present study was to assess the effectiveness of MAS and AUS in diagnosing AA.

Materials and Methods: The present study was designed as a study of Diagnostic Accuracy and was carried out using STARD guidelines at a Tertiary Care Teaching Hospital in India. Prospective collection of data of 100 consecutive patients (70 male and 30 female) who were taken up for Emergency appendectomy for AA during the period from April 2009 to April 2011 was done. Patients with complicated Appendicitis, e.g., perforation-peritonitis, abscess; appendicular lump and pregnant women were excluded. Sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), Likelihood Ratios (LR+ and LR-), Diagnostic Odds Ratio (DOR) and Negative Appendectomy Rate (NAR) were calculated for MAS and AUS by standard statistical calculators.

Results: The present study included 70 males and 30 females belonging to various ages ranging from 11-62 years. Majority of patients (42%) were in their third decade of life. A total of 76% of patients who underwent surgery for AA had MAS of ≥7. All the 24% remaining patients had MAS of 4-6. Overall AUS revealed inflamed appendix in 67% cases, while in the rest, either the appendix could not be visualised or was reported as normal. Sensitivity, specificity, PPV, NPV, LR+, LR-, DOR and NAR of MAS and AUS were 81.61%, 61.54%, 93.42%, 33.33%, 2.12, 0.30, 7.10, 6.58%; and 71.26%, 61.54%, 92.54%, 24.24%, 1.85, 0.47, 3.97, 7.46% respectively. Between the sexes, diagnostic parameters of MAS were slightly better in males. In contrast, in females the parameters of AUS fared marginally better. AUS had much better diagnostic accuracy in diagnosing AA in MAS <7, when compared to MAS ≥7.

Conclusion: The MAS is a good diagnostic tool for AA and should be adequate in uncomplicated AA, if score is ≥7. In those patients where the score is 4-6, AUS should be added to aid in early diagnosis and prompt surgical management of AA. The AUS is also recommended in female patients with suspected AA.

Keywords: Diagnostic accuracy, Emergency appendectomy, Gender, Negative appendectomy rate

INTRODUCTION

The AA is among the common surgical emergencies affecting both sexes; and it is well known that an emergency appendectomy is the treatment of choice to prevent complications of AA that include perforation-peritonitis, which has its attendant high morbidity and mortality [1]. It is also a fact that even today the diagnosis remains a challenge. As the diagnosis of AA is mostly a clinical one, many scoring systems have been practiced to mitigate the subjectivity usually associated with any clinical diagnosis, the most popular among these being Alvarado Score and the MAS [2,3]. Many laboratory parameters and imaging modalities have also been used as adjuncts to the clinical findings. Despite all this, AA is still difficult to diagnose because of various mimicking conditions, particularly in females. There is also a tendency to over diagnose AA which results in high rate of negative appendectomies that adds to the burden of morbidities.

The present study aimed to find the accuracy with which MAS and AUS can diagnose AA by correlating each modality with the final histopathological diagnosis obtained after an emergency appendectomy.

MATERIALS AND METHODS

The present study of diagnostic accuracy was done by enrolling consecutive patients (after taking clearance from Hospital Ethics Committee) who underwent emergency appendectomy for AA, over two years, from April 2009 to April 2011, at a Tertiary Care Teaching Hospital in India. The present study recruited 100 patients which included 70 males and 30 females belonging to various ages ranging from 11 to 62 years. Majority of patients (42%) were in their third decade of life, while only 6% patients were older than forty years. Patients with complicated Appendicitis, e.g., perforation, abscess; appendicular lump and pregnant women were excluded.

The data was recorded prospectively in the form of demographic profile of the patients, their clinical parameters, MAS, AUS findings, intraoperative findings and the final Histopathology (HPE) report. All patients were assigned MAS by the principal investigator, as per standard format, and they were divided into two groups: one with MAS ≥7, and the other with MAS <7 [Table/Fig-1].

Items	Score
Symptoms	
Migratory right iliac fossa pain	1
Anorexia	1
Nausea/vomiting	1
Signs	
Tenderness right iliac fossa	2
Rebound tenderness right iliac fossa	1
Elevated temperature (> 99.5°F)	1
Investigation	
Leucocytosis	2
Maximum score	9

[Table/Fig-1]: Modified alvarado score format used.

The AUS was done in all patients, but by different operators, which also included radiology residents, based on the time of the day, as per hospital policy in practice. The AUS findings were noted as inflamed appendix, normal appendix or 'appendix not seen'. The HPE was reported by different pathologists during the course of the present study and the report was endorsed as AA or normal appendix.

STATISTICAL ANALYSIS

The MAS and AUS data were individually cross tabulated with HPE reports. The results were analysed statistically using standard online calculators. The sensitivity, specificity, PPV, NPV, Likelihood Ratios (LR+ and LR-), Diagnostic Odds Ratio (DOR) and Negative Appendectomy Rate (NAR) of MAS and AUS were calculated as per STARD guidelines.

RESULTS

The present study recruited 100 patients which included 70 males and 30 females belonging to various ages ranging from 11 to 62 years. Majority of patients (42%) were in their third decade of age, while only 6% patients were older than forty years.

Approximately 76% patients who underwent surgery for AA had MAS of ≥7. Almost all the 24 remaining patients had MAS of 5 or 6, except one who had a score of 4. As this patient's AUS was suggestive of AA, he was taken up for surgery and HPE subsequently confirmed AA. Overall AUS revealed inflamed appendix in 67% cases, while in the rest, either the appendix could not be visualised or was reported as normal.

The results found on individual cross tabulation of MAS with HPE and that of AUS with HPE are depicted in [Table/Fig-2,3]. Based on this, various diagnostic accuracy parameters were calculated and the comparison data is given in [Table/Fig-4]. Also, the analysis of the differences between MAS and AUS findings in males and females in the present study population is shown in [Table/Fig-5-7].

	AA on HPE	Normal appendix on HPE	Total
MAS ≥7	71	5	76
MAS <7*	16	8	24
	87	13	100

[Table/Fig-2]: Crosstabulation of MAS with HPE.
MAS: Modified alvarado score; AA: Acute appendicitis; HPE: Histopathology
All had scores of 4-6, no one had scores of 1-3

	AA on HPE	Normal appendix on HPE	Total
AA on AUS	62	5	67
Normal or non-visualised appendix on AUS	25	8	33
	87	13	100

[Table/Fig-3]: Crosstabulation of AUS with HPE.
AUS: Abdominal ultrasound; HPE: Histopathology; AA: Acute appendicitis

Statistical parameters	Values of MAS (95% CI)	Values of AUS (95% CI)
Sensitivity	81.61% (71.86% to 89.11%)	71.26% (60.57% to 80.46%)
Specificity	61.54% (31.58% to 86.14%)	61.54% (31.58% to 86.14%)
PPV	93.42% (87.64% to 96.60%)	92.54% (86.02% to 96.15%)
NPV	33.33% (21.25% to 48.10%)	24.24% (15.69% to 35.50%)
LR+	2.12 (1.06 to 4.25)	1.85 (0.92 to 3.73)
LR-	0.30 (0.16 to 0.55)	0.47 (0.27 to 0.80)
DOR	7.10 (2.05 to 24.58)	3.97 (1.18 to 13.31)
NAR	6.58%	7.46%

[Table/Fig-4]: Comparison of diagnostic values and NAR between MAS and AUS.
MAS: Modified Alvarado score; AUS: Abdominal ultrasound; NPV: Negative predictive value; PPV: Positive predictive value; LR+ and LR-: Likelihood ratios; DOR: Diagnostic odds ratio; NAR: Negative appendectomy rate

	AA on HPE	Normal appendix on HPE	Total
Males			
MAS ≥7	50	3	53
MAS 6 or less	11	6	17
	61	9	70
Females			
MAS ≥7	21	2	23
MAS 6 or less	5	2	7
	26	4	30

[Table/Fig-5]: Crosstabulation of MAS with HPE in male and female patients.
MAS: Modified alvarado score; HPE: Histopathology; AA: Acute appendicitis

	AA on HPE	Normal appendix on HPE	Total
Males			
AA on AUS	45	4	49
Normal or non-visualized appendix on AUS	16	5	21
	61	9	70
Females			
AA on AUS	17	1	18
Normal or non-visualized appendix on AUS	9	3	12
	26	4	30

[Table/Fig-6]: Crosstabulation of AUS with HPE in male and female patients.
AUS: Abdominal ultrasound; HPE: Histopathology; AA: Acute appendicitis

Statistical parameters	MAS		AUS	
	Male	Female	Male	Female
Sensitivity	81.97%	80.77%	73.77%	65.38%
Specificity	66.67%	50.00%	55.56%	75.00%
PPV	94.34%	91.30%	91.84%	94.44%
NPV	35.29%	28.57%	23.81%	25.00%
LR+	2.46	1.62	1.66	2.62
LR-	0.27	0.38	0.47	0.46
DOR	9.09	4.20	3.52	5.67
NAR	5.66%	8.70%	8.16%	5.56%

[Table/Fig-7]: Comparison of diagnostic values and NAR of MAS and AUS between male and female patients.
MAS: Modified alvarado score; AUS: Abdominal ultrasound; NPV: Negative predictive value; PPV: Positive predictive value; LR+ and LR-: Likelihood ratios; DOR: Diagnostic odds ratio; NAR: Negative appendectomy rate

To understand the benefit of adding AUS to MAS, subgroup analysis was done between MAS ≥7 and MAS <7, the data of which is presented in [Table/Fig-8,9]. In the end, of the 100 cases who underwent surgery based on the combination of MAS and AUS findings, 13 were found to have normal appendix on HPE with an

	AA on HPE	Normal appendix on HPE	Total
MAS≥7			
AA on AUS	48	3	51
Normal or non-visualised appendix on AUS	23	2	25
	71	5	76
MAS<7			
AA on AUS	14	2	16
Normal or non-visualised appendix on AUS	2	6	8
	16	8	24

[Table/Fig-8]: Crosstabulation of AUS with HPE in patients with MAS ≥7 and MAS <7.
MAS: Modified alvarado score; AUS: Abdominal ultrasound; HPE: Histopathology; AA: Acute appendicitis

Statistical parameters	AUS in MAS ≥7 (95% CI)	AUS in MAS <7 (95% CI)
Sensitivity	67.61% (55.45% to 78.24%)	87.50% (61.65% to 98.45%)
Specificity	40.00% (5.27% to 85.34%)	75.00% (34.91% to 96.81%)
PPV	94.12% (88.48% to 97.09%)	87.50% (67.51% to 95.93%)
NPV	8.00% (2.75% to 21.12%)	75.00% (43.58% to 92.10%)
LR+	1.13 (0.54 to 2.35)	3.50 (1.04 to 11.79)
LR-	0.81 (0.26 to 2.49)	0.17 (0.04 to 0.65)
DOR	1.39 (0.22 to 8.91)	21.00 (2.37 to 185.94)
NAR	5.88%	12.50%

[Table/Fig-9]: Comparison of diagnostic values and NAR of AUS between MAS ≥7 and MAS <7.
MAS: Modified alvarado score; AUS: Abdominal ultrasound; NPV: Negative predictive value; PPV: Positive predictive value; LR+ and LR-: Likelihood ratios; DOR: Diagnostic odds ratio; NAR: Negative appendectomy rate

overall NAR of 13% (12.86% in males and 13.33% in females). If MAS was the sole basis for diagnosis, NAR was calculated to be 6.58% in patients with MAS ≥7 but it went up to 33.33% in those with MAS <7. Similarly, if only AUS was taken into account, NAR was found to be 7.46% in AUS confirmed AA but the value rose to 24.24% if AUS was negative for AA.

DISCUSSION

An early and accurate diagnosis of AA can be made clinically if typical symptoms and signs are present and there is associated leucocytosis. These common clinical criteria have been incorporated into various scoring systems, most popular being MAS. MAS has the advantage over Alvarado score as it does not include 'shift to the left' criterion, which many of the laboratories do not routinely report [3]. We found MAS to have high sensitivity (81.61%) and good PPV (93.42%) in present study, though the specificity (61.54%) was average and NPV (33.33%) was low. The MAS aided us in taking the decision to operate and we had an NAR of 6.58% in the patients with MAS ≥7. In present analysis of the differences of MAS between the genders, we found it to be mostly comparable with slightly better specificity (66.67% versus 50.00%), better DOR (9.09 versus 4.20) and lower NAR (5.66% versus 8.70%) in males.

A systematic review of Alvarado score by Ohle R et al., found it to be a useful diagnostic 'rule out' tool which was well calibrated in men, but unreliable in children and had a tendency to over diagnose AA in women [4]. In a study by Dey S et al., the reported sensitivity of Alvarado score was 94.2%, specificity was 70%, PPV 86.9% and NPV 69.8% with no marked difference between the genders except for better specificity and NPV in males [5]. However, Rithin PS et al., reported that MAS had better overall specificity of 92.31% and it went up to 100% in the females; but the NAR was also reported to be higher in females (30.76% versus 6.75% in males) in their study, unlike present study [6]. In a study by Ozkan S et al., the sensitivity & PPV of Alvarado score was found to be better in males (64.3% versus 28.6%; and 90% versus 66.7%, respectively) while specificity was better in females (75% versus 57.1%) [7].

Hence, clinical scoring systems have their limitations. It is reported that, in 20-33% of patients, clinical features and laboratory findings are equivocal and may confound the diagnosis [8]. Various imaging modalities have been used as adjuncts in diagnosing AA. These include AUS, CT scan and MRI of the abdomen. Diagnostic Laparoscopy is also an option in acute abdomen with uncertain diagnosis [9]. Of the imaging options, AUS is the most commonly used as it is widely available, economical and safe [9]. However, it has the disadvantage of inter-operator variability, almost like a clinical examination.

In the present study, overall diagnostic accuracy parameters of AUS were similar to MAS, with slightly lower sensitivity (71.26% versus 81.61%), lower NPV (24.24% versus 33.33%), lower DOR (3.97 versus 7.10), and marginally higher NAR of 7.46%. When we analysed the differences of AUS between the genders, though the sensitivity was found to be lesser (65.38% versus 73.77%) in females, other parameters appeared better. There was higher specificity (75.00% versus 55.56%), marginally higher DOR (5.67 versus 3.52) and lower NAR (5.56% versus 8.16%) in females. So AUS seems beneficial in females as it helps in clearing the diagnostic confusion caused by many mimicking conditions in them.

Ozkan S et al., found the following values of AUS which were similar to present study: sensitivity 71.2%, specificity 47%, PPV 82.2% and NPV 31.8% [7]. Nasiri S et al., found AUS to have sensitivity of 71.2%, specificity 83.3%, PPV 97.4%, NPV 25% and NAR of 10.7% while MAS was found to have sensitivity of 65.7%, specificity 37.5%, PPV 89.8% and NPV 11.5% [10]. He also reported that AUS was performed significantly more in women than men (95% versus 71%) as clinical modalities were not enough [10]. However, other studies have reported better diagnostic values for AUS. Douglas CD et al., reported better overall sensitivity and specificity of 94.70% and 88.90%, respectively [11]. Another study by Toorenvliet BR et al., found a higher sensitivity of 91% and specificity of 98%, while the PPV was 94% and NPV was 97% [12]. In a systematic review, Terasawa et al., published that sensitivity of AUS was 86%, specificity 81%, LR+ 5.8 while LR- was 0.19 [13].

Lower sensitivity and specificity of AUS in present study were probably due to different radiologists, including radiology residents, with different experiences doing the AUS of different patients. A study by Lameris W et al., found lower sensitivity but equal specificity in AUS by unsupervised radiology residents when compared to radiologists or supervised residents [14]. This was also corroborated by another study which, in addition found that sensitivity was lower in female patients when done by residents [15]. However, Randen et al., found that the sensitivity, specificity and PPV were comparable between radiologists and residents [16]. The AUS reporting by residents could be a limitation of this study but it can be considered as strength instead, as the data generated is closer to the actual practice that happens in the teaching hospitals and hence it is more relevant.

In the present study, the actual benefit of AUS was seen in the patients with MAS <7. These are the subset of patients where clinical decision making is difficult and an imaging adjunct would be most helpful. In the present study of patients with MAS <7, AUS had much better sensitivity (87.50% versus 67.61%), specificity (75.00% versus 40.00%), NPV (75.00% versus 8.00%), and a much higher DOR (21.00 versus 1.39) when compared to MAS ≥7. Pipal DK et al., evaluated various test combinations and found that combination of Alvarado score and AUS gave the highest sensitivity (97.8%) and specificity (70%) but this was observed when MAS ≥7 [17]. Similarly, Nautiyal H et al., found improved diagnostic accuracy with combination of MAS and AUS but did not report any advantage inthe patients with MAS <7 [18]. A study by Kurane SB et al., mentions that false negatives were reduced by adding AUS to patients with MAS <7 [19]. However, no study so far has statistically reported the definite advantage of AUS in MAS <7 as was observed in the present study.

As we had evaluated only those subjects who had undergone emergency appendectomy for a suspected diagnosis of AA so as to achieve HPE correlation, a sample selection bias may be reported, because all the patients in the present study with MAS <7 had scores of 4-6 and there were none with MAS scores 1-3. But as we had taken consecutive patients who had undergone the surgery, all patients who had MAS scores <4 did not undergo appendectomy and thereby got excluded from the study. This suggests that MAS <4 can be used as a score to rule out AA, but it is beyond the ambit of the present study.

CONCLUSION

The MAS is a good diagnostic tool for AA and should be adequate in uncomplicated AA, if score is ≥7. In those patients where the score is 4 to 6, AUS should be added to aid in early diagnosis and

prompt surgical management of AA. AUS is also recommended in female patients with suspected AA. The quest for finding the perfect balance between avoiding the complications of a perforated appendix and that of the morbidity of a negative appendectomy is still on.

REFERENCES

[1] Stewart B, Khanduri P, McCord C, Ohene-Yeboah M, Uranues S, Rivera F, et al. Global disease burden of conditions requiring emergency surgery. Br J Surg. 2014;101(1):e9-22.
[2] Alvarado A. A practical score for the early diagnosis of acuteappendicitis. Ann Emerg Med. 1986;15(5):557-64.
[3] Kalan M, Talbot D, Cunliffe WJ Rich AJ. Evaluation of the modified Alvarado score in the diagnosis of acute appendicitis: a prospective study. Ann R Coll Surg (Engl). 1994;76(6):418-19.
[4] Ohle R, O'Reilly F, O'Brien KK, Fahey T, Dimitrov BD. The Alvarado score for predicting acute appendicitis: a systematic review. BMC Medicine. 2011;9:139.
[5] Dey S, Mohanta PK, Baruah AK, Kharga B, Bhutia KL, Singh VK. Alvarado scoring in acute appendicitis-a clinicopathological correlation. Indian J Surg. 2010;72(4):290-93.
[6] Rithin PS, Agarwal A, Budigi B. Evaluation of modified Alvarado scoring system in acute appendicitis at Vydehi Institute of Medical Sciences and Research Centre, Bangalore, Karnataka, India. Int Surg J. 2017;4(7):2118-22.
[7] Ozkan S, Duman A, Durukan P, Yildirim A, Ozbakan O. The accuracy rate of Alvarado score, ultrasonography, and computerized tomography scan in the diagnosis of acute appendicitis in our center. Niger J Clin Pract. 2014;17:413-18.
[8] Lane MJ, Katz DS, Ross BA, Clautice-Engle TL, Mindelzun RE, Jeffrey RB Jr. Unenhanced helical CT for suspected acute appendicitis. AJR Am J Roentgenol. 1997;168(2):405-09.
[9] Alvarado A. How to improve the clinical diagnosis of acute appendicitis in resource limited settings. World J Emerg Surg. 2016;11:16.
[10] Nasiri S, Mohebbi F, Sodagari N, Hedayat A. Diagnostic values of ultrasound and theModified Alvarado Scoring System in acute appendicitis. Int J Emerg Med. 2012;5:26.
[11] Douglas CD, Macpherson NE, Davidson PM, Gani JS. Randomised controlled trial of ultrasonography indiagnosis of acute appendicitis, incorporating the Alvarado score. BMJ. 2000;321(7266):1-7.
[12] Toorenvliet BR, Wiersma F, Bakker RFR, Merkus JWS, Breslau PJ, Hamming JF. Routine ultrasound and limited computed tomography for the diagnosis of acute appendicitis. World J Surg. 2010;34:2278-85.
[13] Terasawa T, Blackmore CC, Bent S, Kohlwes RJ. Systematic review: computed tomography and ultrasonography to detect acute appendicitis in adults and adolescents. Ann Intern Med. 2004;141(7):537 46.
[14] Laméris W, van Randen A, van Es HW, van Heesewijk JPM, van Ramshorst B, Bouma WH, et al. Imaging strategies for detection of urgent conditions in patients with acute abdominal pain: diagnostic accuracy study. BMJ. 2009;338:b2431.
[15] Gaitini D, Beck-Razi N, Mor-Yosef D, Fischer D, Itzhak OB, Krausz MM, et al. Diagnosing acute appendicitis in adults: accuracy of color Doppler sonography and MDCT compared with surgery and clinical follow-up. AJR Am J Roentgenol. 2008;190:1300-06.
[16] van Randen A, Laméris W, van Es HW, van Heesewijk HP, van Ramshorst B, Ten Hove W, et al. A comparison of the accuracy of ultrasound and computed tomography in common diagnoses causing acute abdominal pain. Eur Radiol. 2011;21:1535-45.
[17] Pipal DK, Kothari S, Shrivastava H, Soni A, Pipal V. To evaluate the diagnostic accuracy of Alvarado score, C-reactive protein, ultrasonography and computed tomography in acute appendicitis and to correlate them with operative and histological findings. Int Surg J. 2017;4(1):361-67.
[18] Nautiyal H, Ahmad S, Keshwani NK, Awasthi DN. Combined use of modified Alvarado score and USG in decreasing negative appendicectomy rate. Indian J Surg. 2010;72(1):42-48.
[19] Kurane SB, Sangolli MS, Gogate AS. A one year prospective study to compare and evaluate diagnostic accuracy of modified Alvarado score and ultrasonography in acute appendicitis, in adults. Indian J Surg. 2008;70(3):125-29.

PARTICULARS OF CONTRIBUTORS:
1. Senior Resident, Department of Surgical Gastroenterology, Army Hospital (Research and Referral), Delhi Cantt, New Delhi, India.
2. Associate Professor, Department of Surgery, Base Hospital and Army College of Medical Sciences, Delhi Cantt, New Delhi, India.
3. Assistant Professor, Department of Pathology, Base Hospital and Army College of Medical Sciences, Delhi Cantt, New Delhi, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Sukumar Santosh Kumar,
Associate Professor, Department of Surgery, Base Hospital and Army College of Medical Sciences,
Delhi Cantt, New Delhi-110010, India.
E-mail: sskumar9169@gmail.com

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