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Efficacy of modified Alvarado score combined with ultrasound in the diagnosis of acute appendicitis: a prospective analytical study

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Background: Appendicitis is the most common surgical emergency encountered in the emergency department, and diagnosis is difficult at times. Imaging and various clinical scoring are present to aid in the diagnosis. Ultrasound is an easily accessible modality and can accomplish more than a computed tomography (CT) scan at times. Modified Alvarado score (MAS) includes parameters that do not pose an extra financial burden to the patient. Combining both the imaging and clinical scoring systems, the authors decided to evaluate the combined MAS for the diagnosis of acute appendicitis.

Methods: This is a prospective analytical study conducted in a tertiary hospital for one and a half years. Fifty-five patients with right lower quadrant pain were enroled, and evaluated along with an ultrasound. MAS and combined MAS were obtained, and the results of the histopathological examination were compared.

Results: Out of 55 clinically diagnosed cases who underwent an emergency appendectomy, 27 were males and 28 were females. Of these, 50 cases had acute appendicitis as per histopathological examination. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of the MAS was 42%, 100%, 100%, 20.8%, 47.27%, respectively. The sensitivity, specificity, PPV, NPV and accuracy of the USG were 84%, 40%, 93.3%, 20%, and 80%, respectively. Combining both the scores, the Combined MAS had the sensitivity, specificity, PPV, NPV, and accuracy of 98.18%, 0%, 90.7%, 0%, and 89.09%, respectively.

Conclusion: As the combination of USG has raised the sensitivity and diagnostic accuracy of the MAS, it can be an alternative to CT/MRI imaging for the diagnosis of acute appendicitis in resource-limited settings. This score requires further studies to validate with a larger sample size.

Keywords: appendicitis, combined MAS, modified Alvarado score, ultrasonography

Introduction

Acute appendicitis is one of the most common causes of acute abdomen requiring surgical attention, with a lifetime risk of 8.6% in males and 6.7% in females[1]. The complication rates range from 5.5 to 11%, and death rates range from 0.09 to 1.8%[2–5]. The percentage of negative appendectomy is up to 18.2% and can be as high as 28.7% among women of reproductive age[6]. An accurate clinical diagnosis is still challenging due to atypical clinical presentations, especially in women who are in the reproductive age group and extremes of age[7]. If left untreated, simple appendicitis may progress to perforation and lead to high morbidity and mortality, such that surgeons willingly are inclined to operate even if the diagnosis is uncertain[8]. Many surgeons would accept a negative appendectomy rate even up to 30%, which increases the cost of both the patient and health care system, causing unnecessary burdens given the availability of imaging technology for appendicitis[8]. So, the plausible approach is to lessen the negative appendectomy as well as appendiceal rupture rates. The decrease in negative appendectomies should not cause an increase in perforation rates.

Various clinical scores such as the modified Alvarado score (MAS), Appendicitis Inflammatory Response Score (AIRS), and imaging techniques such as computed tomography (CT), Magnetic resonance imaging (MRI) and ultrasound (USG) are available as diagnostic aid. CT abdomen has a sensitivity of 98.5%, specificity of 98%, negative predictive value (NPV) of 99.5%, and positive predictive value (PPV) of 93.9%; however, it is not a cost-effective or easily available modality. Ultrasound is an easily available test with a short acquisition time and has a visualisation rate ranging from 22 to 98%[9]. Modified Alvarado score has a sensitivity of 82.8%, a specificity of 56%, PPV of 89.3%, and NPV of 42.4%[10].

Various studies have suggested the use of ultrasound as an adjunct in cases where clinical scoring is not definite[11]. A study by Agrawal *et al.*[12] that combined MAS and USG (Combined

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MAS) showed the sensitivity, specificity, PPV, NPV, and accuracy of 99.1%, 72.7%, 97.2%, 88.9%, and 96.6%, respectively, in diagnosing acute appendicitis. Combined Modified Alvarado score thus can be an alternative in resource-limited settings. This study is suitable for our setup, where we must make decisions based on limited laboratory investigations and clinical evaluation.

Methods

This was a prospective analytical study conducted in the Department of Surgery of a tertiary hospital for one and half years between October 2020 and April 2022 to find out the efficacy of the Combined MAS in diagnosing acute appendicitis. The sample size was calculated to be 55, considering the expected sensitivity of 96.6% and 95% confidence interval with the addition of 10% dropout[12]. All patients with the clinical diagnosis of acute appendicitis who underwent emergency appendectomy were included in this study. Patients with appendicular abscess, lump, or peritonitis due to perforation requiring laparotomy, age younger than 14 years, appendiceal neoplasm, and those who underwent conservative management were excluded from the study. This study was approved by the Institutional Review Committee (IRC) of the study site, in line with STROCSS (strengthening the reporting of cohort, cross-sectional, and case-control studies in surgery) guidelines and per the Declaration of Helsinki[13].

Data were collected on a structured proforma covering the relevant variables of the study. At presentation in the emergency, a detailed history was taken with special reference to pain, nausea, anorexia, and vomiting, and a clinical examination was done on every patient with attention to the findings such as fever, tenderness, and rebound tenderness in the right iliac fossa (RIF) and findings were noted. Blood investigations, including total leucocyte count (TLC), and differential leucocyte count (DLC) were performed. The USG machine used in our study was PHILIPS Affiniti 70G with linear probe 5-12. The Preoperative MAS and USG scores were calculated based on the defined parameters for every patient. Patients were diagnosed with acute appendicitis as per clinical acumen and were planned for the surgery only after the informed consent. MAS less than 7 was considered negative and greater than or equal to 7 was considered positive for acute appendicitis[14].

Histopathological examination was taken as the standard for the diagnosis of acute appendicitis. The MAS of 1-4(unlikely) were scored as 1, 5-6(probable) were scored as 2 and those with 7-9(definite) were scored as 3 as shown in Table 1. USG findings were classified as unlikely, probable, and definite features with scores of 1, 2 and 3, respectively, as shown in Table 1[15]. The combined MAS was derived from the addition of these scores and subsequently, the combined score 1–2 was taken as unlikely, 3–4 was taken as probable and 5–6 were considered definite of acute appendicitis. Then, combined scores from 3 to 6 (definite and probable) were taken as test positive, and score 1–2 was taken as test negative, as shown in Table 1. Data were entered and analysed with EPI-INFO. The diagnostic accuracies of the modified Alvarado score and USG were assessed individually using pre-established formulae for sensitivity, specificity, NPV, PPV, and accuracy by using the results presented in Table 2. Infiltration of the muscularis propria by neutrophils was considered diagnostic of acute appendicitis[12]. *P* less than 0.05% was considered statistically significant.

HIGHLIGHTS

- Acute appendicitis is one of the most common causes of acute abdomen requiring surgical attention, with a lifetime risk of 8.6% in males and 6.7% in females.
- Imaging and various clinical scoring are present to aid in the diagnosis. Ultrasound is an easily accessible modality and can accomplish more than a computed tomography (CT) scan at times. Modified Alvarado score (MAS) includes parameters which do not pose an extra financial burden to patient do not pose an extra financial burden to patients.
- Fifty patients (90.9%) had histologically confirmed appendicitis, and 5 (9.1%) were histologically negative, that is 5 cases were falsely diagnosed for acute appendicitis clinically.
- The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of the MAS was 42%, 100%, 100%, 20.8%, 47.27%, respectively. The sensitivity, specificity, PPV, NPV, accuracy of the USG was 84%, 40%, 93.3%, 20%, 80%, respectively.
- Combining both the scores, the combined MAS had the sensitivity, specificity, PPV, NPV, accuracy of 98.18%, 0, 90.7%, 0, 89.09%, respectively.
- Combining both scores increased the sensitivity, PPV and accuracy in diagnosing acute appendicitis, whereas the specificity and NPV is decreased in our study.

Results

In this study, 55 cases were clinically diagnosed as acute appendicitis and underwent emergency open appendectomy. Fifty patients (90.9%) had histologically confirmed appendicitis, and 5 (9.1%) were negative, that is 5 cases were falsely diagnosed for acute appendicitis clinically. Twenty-eight (50.9%) patients were females, 27 (49.1%) patients were males, and the median age of distribution was 30 years. Tenderness (90.9%) followed by leucocytosis (75%) was the most common presentation, whereas the least common presentation was fever (7.3%).

While analysing MAS, 14 (25.5%) patients were grouped under 1–4 (less likely) category, and 20 (36.4%) patients were under 5–6 (probable) category, scored as 1 and 2, respectively, making a total of 34 (61.9%) cases that were negative for acute appendicitis. Twenty-one (38.1%) cases with MAS 7–9 (definite) category were taken as MAS positive in our study and scored as 3. In comparison of the MAS with histopathology out of 55 patients, the total number of acute appendicitis identified by MAS was 21, whereas histologically proven cases were 50, as shown in Table 2. Therefore, the sensitivity, specificity, PPV. NPV and accuracy were 42%, 100%, 100%, 20.8%, and 47.27%, respectively.

Out of 55 patients, 41 (74.5%) had a definite diagnosis of acute appendicitis with USG, whereas probable and unlikely categories consisted of 4 (7.3%) and 10 (18.2%) cases, respectively. A total of 45 cases (81.8%) were diagnosed positive for acute appendicitis by USG findings, out of which

Table 1

Combined MAS test (modified Alvarado score and USG score)

Modified Alvarado score[14]

Symptoms	Score	Total
Migratory right iliac fossa pain	1	1–4: Unlikely 5–6: Probable 7–9: Definite
Nausea/vomiting	1	
Anorexia	1	
Tenderness in right iliac fossa	2	
Rebound tenderness in right iliac fossa	1	
Elevated temperature, > 37.3°C	1	
Leucocytosis > 10000 cells/mm^3	2	
Total	9	
USG findings classification[15]		
USG positive/definitive	USG equivocal/probable	USG negative/ unlikely
Appendicitis.	Equivocal ultrasound.	Normal appendix.
Probable appendicitis.	Non-diagnostic study.	No evidence of appendicitis.
Findings consistent with appendicitis.	Cannot exclude appendicitis.	Normal ultrasound of the RLQ.
Early appendicitis.	CT is recommended if	Visualised compressible
Evidence of perforation.		
Phlegmon," or "phlegmonous changes.		
Suspected perforation with abscess.		
A non-compressible dilated appendix or an		
appendicolith with secondary signs of appendicitis (echogenic fat or focal free fluid).	clinical suspicions remain.	appendix of normal calibre (<7 mm diameter).
	Non-visualised appendix with possible secondary findings.	Non-visualised appendix and no secondary findings.

MAS, USG score, combined score[12]

MAS	USG Score	Combined Score (MAS + USG)	Combined MAS test
1–4 scored as 1	Unlikely scored as 1	1–2 score: Unlikely	Negative
5–6 scored as 2	Probable scored as 2	3–4 score: Probable	Positive
7–9 scored as 3	Definite scored as 3	5–6 score: Definitive	

CT, computed tomography; MAS, modified Alvarado score; RLQ, right lower quadrant; USG, ultrasonography.

three cases were HPE negative (false positive), and out of 10 cases labelled as negative for acute appendicitis by USG, 8 cases had a histological diagnosis of acute appendicitis as shown in Table 2. Therefore, the ultrasound sensitivity, specificity, PPV, NPV, and accuracy were 84%, 40.0%, 93.3%, 20%, and 80.0%, respectively.

After adding up the MAS and USG score, 30 (54.5%) cases were grouped in definite category (score 5–6), 24 (43.6%) cases were grouped in probable (3–4 score), and 1 (1.8%) case in unlikely (1–2 score) category according to Combined MAS which meant a total of 54 (98.2%) cases tested positive (Table 3). On comparing with HPE reports 49 cases out of 54 cases were true positive that is 5 cases were falsely labelled as acute appendicitis, whereas a case that was negative for appendicitis as per the combined MAS score test was a histopathological positive case

Table 2

Comparison of MAS, USG, combined test with HPE

Tests	Total number *N* = 55	HPE positive *N* = 50	HPE negative *N* = 5	*P*
MAS positive	21	21	0	
MAS negative	34	29	5	P*
USG positive	45	42	3	$P = 0.18$
USG negative	10	8	2	
Combined MAS test positive	54	49	5	P*
Combined MAS test negative	1	1	0	

HPE, histopathological examination; MAS, modified Alvarado score; USG, ultrasonography.
*Data do not fulfil the assumption for application of the χ^2 test as the cell value is 0.

(Table 2). Thus, the sensitivity, specificity, PPV, NPV and accuracy were 98.18%, 0%, 90.7%, 0%, and 89.09%, respectively.

Discussion

This study included a total of 55 cases which were operated for clinically suspected acute appendicitis, out of which 50 (90.9%) cases were proven to be acute appendicitis histologically while 5 (9.1%) were negative. Various scoring systems include various signs and symptoms. MAS consists of nine parameters, including symptoms, signs, and laboratory values. Among these parameters, in our study, tenderness was seen in 50 (90.9%), leucocytosis in 41(75%), rebound tenderness in 37 (67.3%), and migratory pain was present among 31(56.4%). These findings are consistent with Andersson *et al.*[16] which showed that rebound tenderness, migratory pain, and tenderness are all significantly associated with appendicitis.

Our study showed 42% sensitivity of MAS, and there were no false positive cases, thereby yielding a specificity of 100%. The PPV and NPV of MAS were 100% and 20.8%, respectively. The overall accuracy of the score came out to be 47.2%. Our study correlates with the sensitivity, specificity, and PPV with Ahmed *et al.*[14] whereas the NPV and accuracy in our study are lower than that in this study, but NPV and accuracy were as low as 11.43% and 68% in Kondoju *et al.* study[17]. The modified Alvarado score consists of various clinical parameters (signs and symptoms), which may vary depending on the subject (male/female, race) or the clinician who elicits them. Thus, the variation may be due to differences in sex distribution.

USG was able to detect 42 cases out of 50 HPE-proven cases, which gives a sensitivity of 84%, specificity of 40.0%, PPV of 93.3%, NPV of 20%, and accuracy of 80%. These readings are comparable with those of other studies, such as those by Nasiri

Table 3

Combined MAS test and score

Combined MAS test	Combined MAS score	Frequency	Percentage	Combined test percentage
Negative	1–2 (unlikely)	1	1.8	1.8
Positive	3–4 (probable)	24	43.7	98.2
	5–6 (definite)	30	54.5	
Total		55	100	100

MAS, modified Alvarado score.

et al.[18] and Narendra *et al*.[19] except with low specificity. This may be because USG findings are dependent on the observer. Body habitus, distended abdomen, female gender, and some other factors make it difficult to exclude acute appendicitis for even the experienced radiologist. In teaching hospitals like ours, different radiologists reported the USG findings, including radiology residents with different experiences in doing ultrasound. This may be a probable reason for lower specificity in our study. The ultrasound reporting by resident doctors could be considered a limitation of this study, but it is also the strength of this study as the data generated is closer to the actual practice that occurs in a teaching hospital like ours.

The Combined MAS sensitivity was 98.18%, the PPV was 90.7% and the accuracy was 89.09%. Five patients were shown positive in the combined MAS test, and five were negative in the HPE analysis. The specificity and NPV were zero. The sensitivity, PPV and accuracy in our study are high, which are similar to other studies such as Kansakar *et al*.[9], and Kurane *et al*.[20] but had significantly lower specificity and negative predictive value. These differences may be due to differences in methodology. In a study conducted by Kansakar *et al*.[9], the combined score for MAS and USG was obtained by adding a positive or negative group in either MAS or USG findings. There was no inclusion of a probable group (MAS/USG findings). Similarly, in a study by Nautiyal *et al*.[21], all the USG negative cases or MAS negative cases underwent conservative management, irrespective of either of the tests being positive, and hence were excluded while analysing combined diagnostic tests. This might have resulted in a variation of the results.

Various studies, such as Pipal *et al*.[22], show that the addition of imaging modalities to the clinical scoring system increases the diagnostic accuracy of the test and Kurane *et al*.[20] which was also shown by our combined score test. A study by Agrawal *et al*.[12] also gave the same conclusion with higher sensitivity, specificity, PPV, NPV, and accuracy that is 99.1%, 63.6%, 96.4%, 87.5%, and 95.8%, respectively, whereas our study had similar results with far less specificity and NPV. This could be because our sample size is small, and individual scores (MAS/USG scores) are highly sensitive. The combined score for positive cases (category 3–6) included most of the positive cases, whereas the combined MAS "unlikely" category that was scored 1–2 (negative group) failed to identify 5 cases of HPE negative, thus making this scoring system, significantly less specific in our study. Our study indirectly implies that the cut-off point of this diagnostic test should be taken more than 2 if the specificity of this test is to be increased. The other explanation of low specificity and NPV might be that we enroled only the cases that were clinically diagnosed and then operated. The other cases that were positive with MAS/USG but not clinically suspected were not included in our study, which might have affected the specificity and NPV of our test as a combined score.

Various studies showed that USG increases the sensitivity and diagnostic yield of the scoring system. Our study also showed increased sensitivity and accuracy by combining MAS and USG as a combined score that is 98.18% and 89.09%, in contrast to the sensitivity and accuracy of MAS that is 42% and 84%, respectively, and USG, that is 47.27% and 80%, respectively, when used alone. A combined MAS positive means there is a high probability that the case has appendicitis, whereas if it is negative, one cannot rule out appendicitis; further investigations are required.

Conclusion

As the combination of USG has raised the sensitivity and diagnostic accuracy of the MAS, it can be an alternative to CT/MRI imaging for the diagnosis of acute appendicitis in resource-limited settings. The use of a combined system score can be helpful in decision-making as it increases the sensitivity, PPV, and accuracy so that patients can be diagnosed in the early stage, preventing possible complications. However, for the validation of the score, investigations are required with a larger sample size.

Ethical approval

This study was approved by the institutional review committee (IRC) of the tertiary care hospital of Nepal on 7 August 2020. All procedures performed in studies involving human participants were in accordance with the ethical standards of IRC and with the 1964 Helsinki Declaration and its later amendments. Ethical approval for this study (Institutional Review Committee - Patan Academy of Health sciences Ref: PSS2012011471) was provided by the Institutional Review Committee - Patan Academy of Health sciences (IRC-PAHS), Lalitpur, Nepal on 1 December 2020. All procedures performed in studies involving human participants were in accordance with the ethical standards of IRC-PAHS and with the 1964 Helsinki Declaration and its later amendments.

Consent

Informed consent was obtained from the participants before conducting the study and written informed consent from parents/caretakers was obtained for those participants aged younger than 18 years.

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Author contribution

S.S., L.R.: conceptualization, data curation, investigation, methodology, project administration, formal analysis, writing original draft, writing—reviewing and editing. S.B., P.G., S.R.: data curation, investigation, methodology, writing original draft, writing—reviewing and editing. S.R.G., E.S.: writing original draft, writing—reviewing and editing. All the authors approved of the final version of the manuscript and agreed to be accountable for all aspects of the work ensuring questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflicts of interest disclosure

There are no conflicts of interest.

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Data availability statement

The data are available through the corresponding author upon reasonable request.

Provenance and peer review

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