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Comparative Analysis of Role of Adult Appendicitis Score (AAS) and Appendicitis Inflammatory Response (AIR) Score in the Diagnosis of Acute Appendicitis

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Abstract: ***This study compares the Adult Appendicitis Score (AAS) and the Appendicitis Inflammatory Response (AIR) score to determine their reliability in diagnosing acute appendicitis. Conducted at a tertiary care hospital with 150 participants, the study found that AAS, with a specificity of 92.18%, is more reliable for patients with severe symptoms, while AIR, with a sensitivity of 91.86%, effectively identifies low-risk cases. Using ROC curve analysis, the study highlights the potential of these scores in reducing unnecessary imaging and negative appendectomy rates. This research underscores the value of clinical scoring systems for risk stratification and personalized patient management.***

Keywords: Acute appendicitis, Adult Appendicitis Score, Appendicitis Inflammatory Response, negative appendectomy, abdominal pain, acute appendicitis, diagnostic accuracy, clinical scoring systems

1. Introduction

Acute and severe abdominal pain is mostly a symptom of intra - abdominal disease and requires emergency admission. Acute appendicitis is found to be among the most common cause of acute abdominal pain [1]. It has been reported that 1 in 15 people may potentially develop appendicitis during their lifetime [2]. About 7 - 10% of the subjects develop appendicitis during their 20's and 30's in a 3: 2 man - woman ratio [3].

Appendicitis is described as the sudden and severe inflammation of the appendix mainly due to the obstruction of its lumen by faecolith, normal stool, infective agents or lymphoid hyperplasia and usually occurs within 24 hrs of onset. Appendix is a narrow tube like, finger shaped organ located at the tip of the cecum that projects from the lower right side of the abdomen [4].

Acute appendicitis is associated with acute abdominal pain starting in the mid - abdomen region and further localising to the Right Iliac Fossa (RIF). The pain may worsen with movement such as walking, coughing, sneezing and could become severe and worsen within hours. If left untreated, acute appendicitis can lead to peritonitis due to the formation of appendicular abscess, inflammatory mass or rupture. Other symptoms adults experience includes anorexia, nausea/vomiting, fever (40% of patients), diarrhea, generalized malaise, urinary frequency or urgency [5].

Causes of RIF pain other than appendicitis include Crohn's disease, diverticulitis, mesenteric adenitis, pelvic inflammatory disease, ectopic pregnancy, ureteric colic, CA cecum and ileocecal tuberculosis [6].

On one hand, as the diagnosis of acute appendicitis is mainly based only on clinical presentation and physical examination, it is very challenging. Hence it is usually diagnosed only at late stages resulting in life threatening complications like perforation of the appendix.

On the other hand, the clinical presentation and symptoms of acute appendicitis are frequently atypical and can be very similar to other diseases, which makes diagnosis difficult. The misdiagnosis of this acute condition has led to the unnecessary and irrelevant removal of a normal appendix, called as negative appendectomy. It was found in 8–30% of patients. Recently, there has been a consistent decline in NAR because of better diagnostic imaging tools [3].

Until recently, a 15% negative appendectomy rate was accepted in order to reduce the perforation rate. Currently, the imaging study of choice in adults for suspected appendicitis is computed tomography (CT), which has reduced the negative appendectomy rates to less than 10% [7]. However, exposure to CT on the abdomen and pelvis once was found to carry an additional cancer risk of 0.2% in a healthy middle - aged adult. Also, making the imaging has an enduring cost [8].

The over - and underuse of imaging studies can be prevented in patients with suspected acute appendicitis with the implementation of clinical risk scores into the diagnostic pathway [9]. Various clinical scoring systems have been introduced to aid in the diagnosis of acute appendicitis but none has been widely accepted.

The Alvarado scoring based on MANTRELS mnemonic is used widely now, but study shows that it is not sensitive enough to aid in the diagnosis of acute appendicitis. The Alvarado score is not sufficient enough and specific in diagnosing acute appendicitis in adults and seems unreliable in differentiating complicated from uncomplicated appendicitis in elderly patients [10]. The RIPASA (Raja Isteri Pengiran Anak Saleha Appendicitis) score shows better sensitivity and specificity than the Alvarado score in Asian population [11].

The World Society of Emergency Surgery (WSES) organized a conference on the diagnosis and treatment of AA in adult patients in 2019 to support the use of new clinical scores like the Adult Appendicitis Score (AAS) and Appendicitis Inflammatory Response (AIR).

These scores make use of physical findings and also simple hematological parameters like serum c - Reactive Protein (CRP) and segmented neutrophils. As an increased level of inflammatory markers like CRP and WBC directly correlate with the degree of risk in AA [12], these new markers can reliably be used for making a diagnosis.

The appendicitis inflammatory response score (AIR) score is based on the same principles of Alvarado scoring to stratify patients to low, medium, or high probability of appendicitis. It was developed by Andersson and Andersson in 2008 based on eight independent variables: Right Lower Quadrant (RLQ) pain, rebound tenderness, muscular defense, WBC count, proportion of neutrophils, CRP, body temperature and vomiting [13].

A new diagnostic score the Adult Appendicitis Score (AAS) was introduced for adult patients with suspected acute appendicitis. The AAS also stratifies patients based on risk thus helping in selectively choosing patients for surgery and thereby helps in reducing the negative appendectomy rate in low - risk individuals.

Rationale: The clinical use of the AAS and AIR score helps to stratify patients according to the risk, thus reducing negative appendectomy and unnecessary use of imaging studies in patients with suspected acute appendicitis. Scoring offers a method for selecting high - risk patients directly to surgery, low - risk patients to outpatient care, and intermediate - risk patients to further investigations. These clinical scores are sufficient to diagnose suspected cases of acute appendicitis to make a quick diagnosis, thus preventing complications.

2. Review of Literature

1) Sammalkorpi, H. E. and Mentula, in their study constructed a new scoring system for more accurate diagnostics of acute appendicitis called as the AAS. Applying the new score into clinical practice could reduce the need of potentially harmful and unnecessary diagnostic imaging. In their study they compared AAS with Alvarado and AIR score. They found that the specificity of AAS was 92.7% in the high probability group. Through logistic regression analyses ROC was plotted. Based on the chosen cut - off values in the ROC analysis, patients were classified into three groups corresponding to probability of appendicitis: high (≥16 points), intermediate (11–15 points), and low (0–10 points) [14].
2) Kollár D, McCartan DP, Bourke M, Cross KS and Dowdall Jin, their study made a comparison of the Alvarado score and the AIR score. In their study, they found that the AIR score is accurate at excluding appendicitis in low - risk patients and more accurate than the Alvarado score at predicting appendicitis in high - risk patients.
3) Grönroos JM and Grönroos P, revealed that Leucocyte count and C-reactive protein are useful in the diagnosis of acute appendicitis. The AAS and AIR score uses these parameters to diagnose appendicitis. This study revealed that the increase in leucocyte count was an early marker of appendicitis, whereas the CRP value increased markedly only after appendiceal perforation or abscess formation [12].
4) In the 2020 update of the WSES Jerusalem guidelines by Di Saverio S, Podda M, De Simone B, it was found that the sensitivity and specificity of AIR score was 92% and 63% respectively. The AIR score was found to be the overall best performer and most pragmatic while the AAS was found to be the most specific [10].

3. Aims and Objectives

Aim

To compare the Adult Appendicitis Score (AAS) and Appendicitis Inflammatory response (AIR) score to find which score is more reliable in the diagnosis of acute appendicitis.

Objectives

To evaluate the AAS and AIR score and use them as the clinical predictors of acute appendicitis to:

- Provide accurate diagnosis with selective use of imaging studies.
- Decrease negative appendectomy rates in low - risk groups
- Reduce hospital admissions in both low - and intermediate risk groups.

4. Materials and Methods

Materials:

a) *Type of study:* Prospective observational study
b) *Study site:* Tertiary care hospital
c) *Duration of study:* 2 months (August 2022 and September 2022)
d) *Sample size:* 150 patients
e) *Inclusion criteria:*
   - age: >19 years
   - presenting with the complaint of right lower quadrant (RLQ) abdominal pain or suspected appendicitis.

f) *Exclusion criteria:*
   - adolescent (10 - 19 years) patients
   - pediatric patients

g) *Selection criteria:* The most common diagnosis for acute appendicitis is made in young patients with an acute abdomen presenting with right lower quadrant pain.

Methodology

The study was conducted only after obtaining approval of the Institutional Ethics Committee (IEC). After obtaining informed oral/written consent from the patients, data collection and lab investigations are carried out.

5ml of blood is collected from the patients. It is then allowed to clot and serum analysis of all hematological parameters is measured. The collected data included clinical signs (tenderness in RLQ, guarding in RLQ, and body temperature) and symptoms (pain in RLQ, migration of pain, vomiting, and anorexia), together with laboratory test results [C - reactive protein (CRP), total leukocyte count, and proportion of neutrophils], as well as time elapsed between the onset of symptoms to presentation.

After the collection of data AAS and AIR scores were calculated to test their reliability. The scoring systems were not used by the surgeon to make a decision about surgery.

Data collection:
After collecting data, AAS (Table 1) and AIR score (Table 2) is calculated. Based on the score; patients are stratified into low, intermediate-, and high - risk groups for appendicitis (Table 3). Calculations include simple mathematical calculations of AAS and AIR score & sensitivity and specificity of the scores.

The medical records are reviewed 1 month after hospital discharge to assess the final histological diagnoses. The data on hospital admissions, patients who underwent appendectomy were reviewed and compared to the reference population.

Statistical analysis:
The ratio of male to female patients was calculated as percentages.

The diagnostic performance of the AAS and AIR score (specificity and sensitivity) is calculated and analyzed using ROC (Receiver Operating Characteristic) curve in SPSS software for Windows, Version 16.0.

Table 1: Adult Appendicitis Score [14]

Symptoms and Findings		Score
Pain in RLQ		2
Pain relocation		2
RLQ tenderness	Women, aged 16–49 years	1
	All other patients	3
Guarding	Mild	2
	Moderate or severe	4
Laboratory tests		
Blood leukocyte count (×109)	⩾7.2 and <10.9	1
	⩾10.9 and <14.0	2
	⩾14.0	3
Proportion of neutrophils (%)	⩾62 and <75	2
	⩾75 and <83	3
	⩾83	4
CRP (mg/L), symptoms <24 h	⩾4 and <11	2
	⩾11 and <25	3
	⩾25 and <83	5
	⩾83	1
CRP (mg/L), symptoms >24 h	⩾12 and <53	2
	⩾53 and <152	2
	⩾152	1

Table 2: Appendicitis Inflammatory Response [15]

Diagnosis	Score
Vomit	1
Pain in RIF	1
Abdominal Defense	
low	1
Mild	2
Severe	3
Temperature >38, 5 C	1
Segmented Neutrophils	
70 - 84%	1
>85%	2
Leukocytes	
>10.0–14.9 x 109/l	1
>15.0 x 109/l	2
CRP	
10–49 g/l	1
>50 g/l	2

Table 3: Management based on risk evaluation [14, 15, 16]

AAS		AIR	SCORE	
⩽10	Low risk	0 - 4	Low risk	No imaging
11–15	Intermediate risk	5 - 8	Intermediate risk	Imaging - MRI/CT
⩾16	High risk	9 - 12	High risk	Surgery without imaging &pathology specimen followed

5. Observation and Results

The study included 150 patients who presented with RLQ pain. From the below figure 1, out of 150 patients, 64% were males and 36% were females. The mean age of presentation was 22.1±12.6 years. The baseline characteristics of the patients are illustrated in table 4.

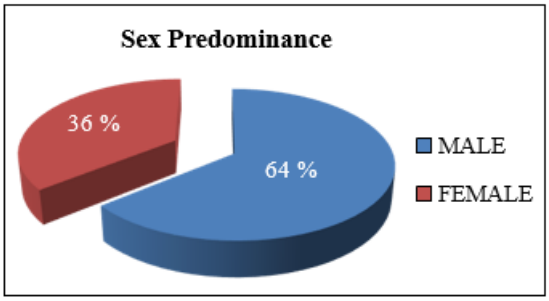

Figure 1: Sex dominance in acute Appendicitis

Table 4: Patient's Characteristics

Items		Frequency	Percentage
Age	Mean ± SD	22.1 ± 12.6	
	Minimum ─ maximum	10 - 34 y	
Sex	Males	96	64%
	Females	54	36%
Diagnosis of Appendicitis	Positive	86	57%
	Negative	64	42%

This study enrolled 150 patients who presented with pain in the RIF who were suspected of appendicitis. For all the patients AAS and AIR scores were calculated and the patients were stratified into high risk, mild risk and low risk based on the scores obtained as shown in figure 2.

Using imaging studies like MRI and CT, it was found that 57 % (86 out of 150 patients) had appendicitis while 42% (64 out of 150 patients) did not have appendicitis. Out of the 86 patients only 73 patients agreed to surgery. All 73 appendices removed surgically were sent for pathological examination for confirmation of diagnosis.

Stratification of patients based on risk

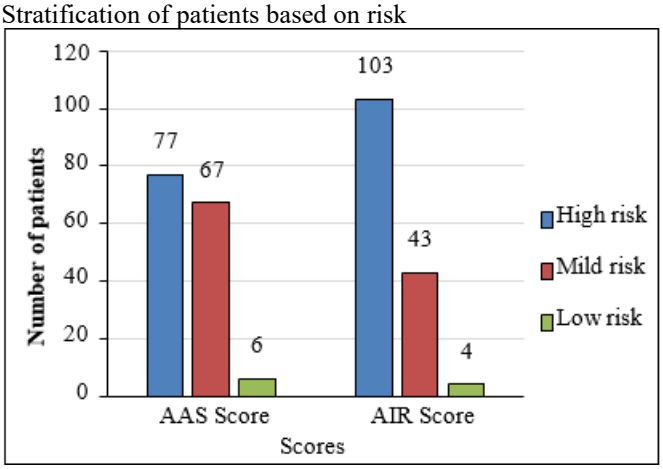

Figure 2: Graph data of stratification of patients based on risk

Pathological diagnosis:
Transmural infiltration with neutrophils in the appendix was used to confirm acute appendicitis.
11 out of the 73 patients had normal appendix.

Calculation of scores:
For the all the 150 patients, history taking, physical examination and the required laboratory tests were carried out to calculate the AAS and AIR score. These scoring systems were not used by the surgeon to make a decision about surgery.

Calculation of AAS:
The AAS was calculated for all the 150 patients and correlated with the imaging studies which were used to rule out acute appendicitis.

As shown in table 4, 86 patients had acute appendicitis which was diagnosed on imaging studies.

72 out of the 86 patients obtained a high score (≥16) with a mode of 16 while the remaining 14 patients obtained a low score (10 - 15) with a mode of 13 indicating false negatives.

For 64 patients, imaging studies showed no significant findings, suggesting negative appendicitis.

5 out of 64 patients obtained a high score (≥16) with a mode of 16, indicating false positives while the remaining 59 patients obtained a low score (10 - 15) with a mode of 10.

Based on this data, sensitivity and specificity were calculated for this score taking cut off score as 16.

Table 4: Sensitivity and specificity data for AAS

	Positive for Appendicitis	Negative For Appendicitis
High Score	72 (a)	5 (b)
Low Score	14 (c)	59 (d)

$$\text{Sensitivity} = \frac{a}{a+c} * 100 = \frac{72}{86} * 100 = 83.72\%$$

$$\text{Specificity} = \frac{d}{b+d} * 100 = \frac{59}{64} * 100 = 92.18\%$$

Calculation of AIR score:
The AIR score was calculated for all the 150 patients correlated with the imaging studies which were used to rule out acute appendicitis.

As shown in table 5, 86 patients had acute appendicitis which was diagnosed on imaging studies.79 out of the 86 patients obtained a high score (9 - 12) with a mode of 11 while the remaining 7 patients obtained a low score (4 - 8) with a mode of 8 indicating false negatives.

For 64 patients imaging studies showed no significant findings, suggesting negative appendicitis.24 out of 64 patients obtained a high score (9 - 12) with a mode of 11, indicating false positives while the remaining 40 patients obtained a low score (4 - 8) with a mode of 4.

Based on this data, sensitivity and specificity were calculated for this score taking cuff off score as 9.

Table 5: Sensitivity and specificity data for AIR score:

	Positive for Appendicitis	Negative For Appendicitis
High Score	79 (a)	24 (b)
Low Score	7 (c)	40 (d)

$$\text{Sensitivity} = \frac{a}{a+c} * 100 = \frac{79}{86} * 100 = 91.86\%$$

$$\text{Specificity} = \frac{d}{b+d} * 100 = \frac{40}{64} * 100 = 62.5\%$$

It is observed that the AAS has more specificity and less sensitivity while AIR score has more sensitivity and less specificity.

ROC curve for comparing the AAS and AIR scores:
Data for plotting the ROC curves for AAS and AIR score was taken from table 6 and table 7 respectively. Seven different cut - off values were taken and determined using ROC analysis. The point where sensitivity and specificity were

closest determined the first cut - off value. Other cut off values are mentioned in table 6 and 7. From the obtained ROC curve, the curve of AAS is more towards the left compared to the curve of AIR score. The area under curve for the AAS (blue) is greater than the area under curve for the AIR score (red).

- X axis: 1 – Specificity
- Y axis: Sensitivity
- TPR: True Positive Rate
- FPR: False Positive Rate

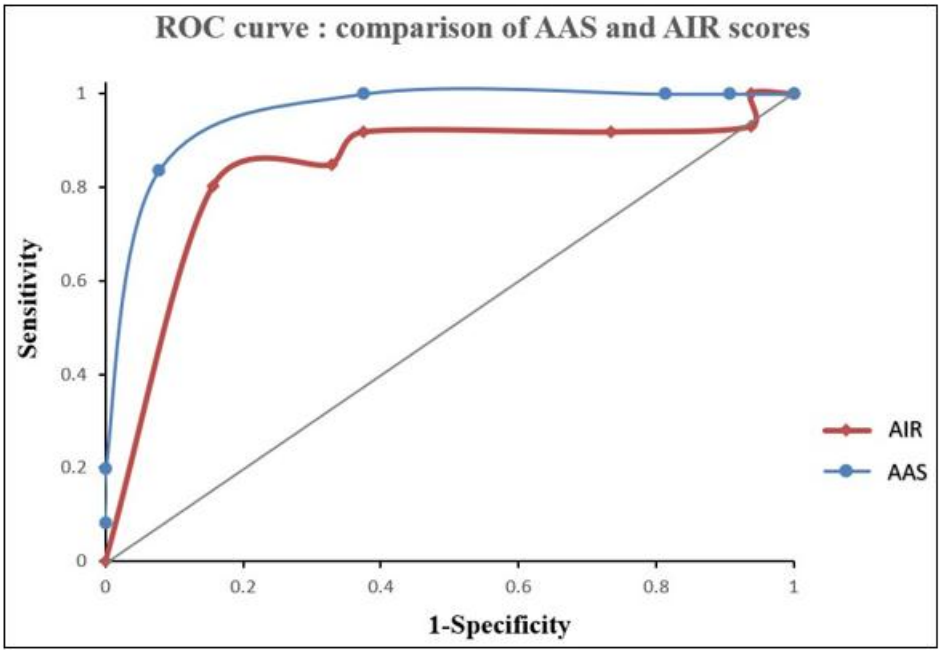

Figure 3: ROC curve comparison of AAS and AIR score

Table 6: Data for calculation of ROC curve for AAS

cut - off	FPR	TPR
10	1	1
12	0.9062	1
13	0.8125	1
14	0.375	1
16	0.0781	0.8372
17	0	0.1977
18	0	0.0814

Table 7: Data for calculation of ROC curve for AIR score

cut - off	FPR	TPR
4	1	1
5	0.9375	1
7	0.9375	0.9302
8	0.7343	0.9186
9	0.375	0.9186
10	0.3281	0.8488
11	0.1562	0.8023

Negative Appendectomy Rate (NAR)

Out of the 86 patients with positive appendicitis, only 73 patients were operated and 11 patients had a normal appendix.

$$NAR = \frac{11}{73} * 100 = 15.06\%$$

6. Discussion

One of the most common causes of abdominal pain is acute appendicitis which presents as severe pain in the RIF. As a lot of other conditions can also present as RIF pain, it is very difficult to make a diagnosis based only on physical examination and clinical findings. Different scores have been introduced to make a quick diagnosis and to stratify patients according to risk for early management, thus preventing complications.

Out of the 150 patients, 64% were males and 36% were females. Appendicitis commonly occurs in males compared to females. This is consistent with the study done by Bruno Von Muhlen, Orli Franzon; Murilo Gamba Beduschi, Nicolau Kruel, Daniel Lupselo which showed that appendicitis occurs in a ratio of 3: 2 man - woman ratio [13].

The age of the patients was found to be between 10 to 34 years (22.1±12.6) this value correlates with the study by Mark W. Jones; Richard A. Lopez; Jeffrey G. Deppen. [4]

To calculate the AAS and AIR scores, physical findings and hematological parameters like CRP, WBC and segmented neutrophils were taken. In almost all of the patients with positive appendicitis either all 3 parameters or individual parameters were found to be elevated. The raised value of the CRP was directly related to the severity of appendicitis (p - value <0.05). CRP monitoring thus increases the diagnostic accuracy of acute appendicitis. However, the diagnostic accuracy of CRP is not significantly greater than WBC and proportion of segmented neutrophils. These results correlate with this study where a combination of these three tests were significantly elevated [17].

In this study, we aim at comparing the accuracy of two scores, AAS and AIR score. The true positives are the patients who

were correctly classified as acute appendicitis. The true positive rate tells what proportion of patients with acute appendicitis were correctly classified. The false positives are the appendicitis negative patients who were incorrectly classified as having acute appendicitis and the true negatives are the patients correctly classified as not having appendicitis. On evaluating both the scores for all the 150 patients, the AAS showed 72 true positives and 5 false positives while the AIR score showed 79 true positives and 24 false positives. The sensitivity and specificity values came out to be 83.72% & 92.18% respectively for AAS and 91.86% & 62.5 % respectively for AIR score. This is in agreement with WSES appendicitis guidelines by Salomone di saverio who reported a specificity of 93.33% for AAS and sensitivity and specificity of 92% and 63% respectively for AIR score.

The ROC curve graphs a simple way to summarize all the information. The y axis shows the true positive rate, which also represents sensitivity. The x axis shows the false positive rate which represents 1− specificity. The false positive rate (FPR) signifies the proportion of appendicitis negative patients who were incorrectly classified and are false positives.

A point of (1, 1) where the TPR and FPR have a value of 1 on the ROC curve means that even though we correctly classified all the appendicitis positive patients, we incorrectly classified all the appendicitis negative patients. The diagonal line shows where the TPR is equal to the FPR. The ROC curve for AAS moved to the left on increasing cut off value. This means that the AAS was more specific at higher scores (≥16).

The ROC curve for AIR score moved to the left on decreasing the cut off value showing that the AAS was more specific at lower scores. From figure 3, it can be said that the AAS is a better diagnostic score than the AIR score for the diagnosis of acute appendicitis.

7. Significance of the Study

Since the specificity value is above 90%, this score can be used reliably and should be more widely accepted as one among the best modalities to make a diagnosis of acute appendicitis.

On the basis of the obtained scores, patients were stratified into high risk, mild risk and low risk for a stepwise personalized approach towards the management of appendicitis.

If these scores were implemented, only the high - risk patients will be selected for surgery, thus reducing the rate of negative appendectomy in the mild risk patients. The negative appendectomy rate was found to be 15.06%. However, if diagnostic scores like AAS and AIR were used the NAR can be decreased. As these scores stratify patients according to risk and only high - risk patients will be selected for surgery, the NAR can be decreased in both intermediate and low risk individuals.

Also, according to these scores low risk patients don't need imaging at all, therefore eliminating the use of unnecessary imaging. Similarly, hospital admissions can also be reduced.

On the other hand, for AIR score the specificity is around 62.5%. The review by Kularatna et al. recently summarized that the AIR score performed well with a sensitivity of 92% and specificity of 63% [18]. The specificity of the AIR score is very low compared to the AAS. (specificity = 92.18%) This is probably because out of the 64 appendicitis negative patients, 24 patients got a falsely elevated score (≥ 9). Since the cut off value for this score was lower compared to the AAS, a higher number of false positives were obtained. However, there are other studies that which show the specificity of AIR score to be higher [19]. As physical findings like pain in RLQ, pain relocation, RLQ tenderness and guarding are very subjective and difficult to evaluate, it may deviate the final score giving false positives. Migration of pain, an important specific symptom in the diagnosis of acute appendicitis is not included in the AIR score. This may be the reason for the low specificity of the AIR score.

8. Conclusion

From this study it can be concluded that the AAS seems to be a better score for the diagnosis of acute appendicitis as inferred from the ROC curve. As the AAS has a 92.18 % specificity at higher cut off scores, it can be used reliably in patients who present with severe abdominal pain and guarding. As the AIR score shows more specificity at a lower cut off scores, it can be used to identify intermediate and low risk appendicitis patients. Both the scores are sufficiently sensitive to exclude acute appendicitis. Further work is required for further evaluation of these scores and to establish a well agreed clinical guide for the management of acute appendicitis.

The below topics are suggested for further study:

- With a wider population, similar study shall be done
- The sensitivity and specificity of the scores for male and female population separately
- Comparison of accuracy of imaging studies and clinical scores for diagnosing acute appendicitis
- Management of acute appendicitis based on scoring systems

9. Summary

This study compares the Adult Appendicitis Score (AAS) and the Appendicitis Inflammatory Response (AIR) score to determine their reliability in diagnosing acute appendicitis. Conducted at a tertiary care hospital with 150 participants, the study found that AAS, with a specificity of 92.18%, is more reliable for patients with severe symptoms, while AIR, with a sensitivity of 91.86%, effectively identifies low - risk cases. Using ROC curve analysis, the study highlights the potential of these scores in reducing unnecessary imaging and negative appendectomy rates. This research underscores the value of clinical scoring systems for risk stratification and personalized patient management

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