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Comparative Study of Modified Alvarado Score, Appendicitis Inflammatory Response Score and New Adult Appendicitis Score in Predicting the Accuracy of Diagnosing Acute Appendicitis

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Abstract
Background – *New adult appendicitis score (NAAS) is more convenient and accurate scoring system in predicting acute appendicitis. As more data is required before clinical application, we compared modified Alvarado score, appendicitis inflammatory response score and new adult appendicitis score simultaneously.*
Methods – We analysed the data of 90 patients who presented to the department of General Surgery, TATA Main Hospital, Jamshedpur, Jharkhand with the features of acute appendicitis between April 2015 and April 2017. The comparison was carried out considering the age, sex, CRP, BMI, pain, migratory RIF pain, vomiting, fever, leucocytosis, polymorphs, anorexia, rebound tenderness, RIF tenderness and guarding. The predictive accuracy of scoring system was measured using the area under the receiver-operating curve (AUC).
Results – *The area (95% CI) under the curve value is 0.868 (0.814-0.922) with a standard error value of 0.027. New adult appendicitis score was found to be better predictor as it predicted 87% who had appendicitis. The area (95% CI) under the curve value is 0.482 (0.362-0.602) with a standard error value of 0.061. Appendicitis inflammatory response score predicted 48% who had appendicitis. The area (95% CI) under the curve value is 0.528 (0.401-0.655) with a standard error value of 0.065. Modified Alvarado score predicted 53% who had appendicitis.*
Conclusion – *The New adult appendicitis score was found to be better predictor of diagnosing acute appendicitis than Modified Alvarado score and Appendicitis Inflammatory response score.*
Keywords: *Acute Appendicitis, Appendicitis Inflammatory Response Score, New Adult Appendicitis Score*

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I. Introduction

1.1 Acute appendicitis

Acute appendicitis is the most common indication for emergency surgery worldwide, with incidence of 1.17 per 1000 and lifetime risk of 8.6% in men and 6.7% in women.

Appendicitis is associated with morbidity and mortality as it can progress to perforation and peritonitis if left untreated. Though the lifetime risk of appendicitis is 8.6 % for males and 6.7 % for females, the risk of undergoing appendectomy is much lower for males than for females (12 vs. 23 %) with a male: female ratio of approximately 1.4:1and it occurs most often between the ages of 10 and 30. The incidence is highest in adolescents and young adults, but the incidence of complicated appendicitis shows little variance between different age groups.[1-2]

The classical features of acute appendicitis begin with pain in periumbilical region. It is mostly associated with anorexia, nausea and few episodes of vomiting. As the inflammation progresses the pain shifts to right lower quadrant of the abdomen. Atypical presentation include poorly localized abdominal pain which is seen more commonly in elderly. It may sometimes is associated with pyrexia. Constipation and nausea with profuse vomiting may indicate development of generalized peritonitis after perforation.[3]

Figure 1 Intraoperative picture of appendix in a case of acute appendicitis

1.2 Diagnosis of appendicitis

Although a very common and long-known phenomenon, appendicitis remains a diagnostic challenge for surgeons and emergency physicians. The diagnosis is specially challenging for women of fertile age.[4-6]

Early surgical intervention is the traditional gold standard for preventing appendicular perforation. Clinical diagnosis alone leads to a negative appendectomy rate of 15 to 30%.High rate of unnecessary negative appendectomies, however, leads to unnecessary morbidity and even mortality.[7-8]

The frequent use of computed tomography (CT) with its high sensitivity and specificity in diagnosis of appendicitis has helped to reduce the number of negative appendectomies.[9-10] Preoperative CT seems to benefit most women 45 years of age and younger. [11-12] The use of CT may, however, delay appendectomy in clinically typical cases of acute appendicitis, and therefore even elevate the risk for perforation.[13-14]

Despite numerous studies on AA, many unresolved issues remain, including etiology and treatment. The diagnosis of AA is a constellation of history, physical examination coupled with laboratory investigations, supplemented by selective focused imaging. These can be used in combination in scoring systems. Various clinical scoring systems have been proposed in order to predict AA with certainty, but none has been widely accepted. The role of diagnostic imaging (ultrasound (US), computed tomography (CT) or magnetic resonance imaging (MRI)) is another major controversy.

1.3 Scores for prediction of appendicitis

Diagnosis of acute appendicitis is still a challenging feature. Different scores are used for the validation of diagnosis of acute appendicitis. The Alvarado score, originally described in 1986, is the most widely reported scoring system for acute appendicitis. The development of Appendicitis Inflammatory Response (AIR) score may contribute to diagnosis associating easy clinical criteria and two simple laboratory tests.New adult appendicitis score is one of the newest score used for diagnosis of acute appendicitis now-a-days. There are various other scores used in diagnosing acute appendicitis.

Table 1 Various scores used in diagnosing acute appendicitis

Sr. No.	SCORES	CUT OFF VALUE
1	Fenyo-Lindberg score	10
2	Eskelinen score	55
3	Izbicki score	2
4	Christian score	4
5	Teacher score	3
6	Ohmanns score	8
7	Tzanakis score	8
8	Ripasa score	7.5
9	Lintula score	21

One of the diagnostic strategies include the use of scoring systems, of which the Alvarado score, derived from retrospectively collected data from 305 adult patients in the mid-1980s, is the best known clinical

prediction rule for estimating the risk of appendicitis.[15-19] This score is calculated from symptoms, physical examination, and basic laboratory data and assigns a score from 0 to 10. The original study of this system reported a sensitivity of 81% and specificity of 74% in identifying patients who needed an appendectomy, and subsequent validation studies have showed variable performances of this score. The modified Alvarado score uses the same value categories without the shift to left of leukocytosis, ranging from a score of 0 to 9.Patients with a modified Alvarado score <4 is considered to be at low risk.[20]

An ideal scoring system would work as a tool that speeds up and increases the accuracy of decision-making and at the same time reduces the need of potentially harmful and expensive imaging. Most of the existing diagnostic scores have the weakness of being originally based on retrospective data of patients with appendicitis, a small number of patients, or pediatric patients. In retrospective studies, a potential systematic bias involves ignoring the number and outcome of non-operated patients presenting with clinical suspicion of appendicitis. In children, in comparison to adults, the diagnostic limit of leukocyte count and differential diagnosis of acute abdominal pain vary, and depend on age.[21-22]

The new Adult Appendicitis Score differs from previous scoring systems by taking into account the important effects of gender and duration of symptoms. It helps to categorize patients accurately into three different groups. In addition to the majority of patients that can be safely discharged from the emergency department or assigned directly to surgery, it identifies a group (38% of all patients) that would benefit from further diagnostic studies such as CT.[23]

Scoring systems have been designed to aid in the clinical assessment of patients with acute appendicitis. The Alvarado score is the most well-known and best performing in validation studies, but it has some drawbacks.[24-26]

Its construction was based on a review of patients who had been operated with suspicion of appendicitis, whereas the score is supposed to be used on all patients with suspicion of appendicitis. Also, the score does not incorporate C-reactive protein as a variable, although many studies have shown the importance of C-reactive protein in the assessment of patients with appendicitis.

The recently introduced appendicitis inflammatory response (AIR) score was designed to overcome these drawbacks. This score incorporated the C-reactive protein value in its design and was developed and validated on a prospective cohort of patients with suspicion of acute appendicitis. The scoring system has a high discriminating power and outperforms the Alvarado score.[27]

The present study aims to assess the predictive ability of modified Alvarado score, new Adult Appendicitis Score and appendicitis inflammatory response (AIR) score in predicting acute appendicitis.

II. Review Of Literature

The review of literature was undertaken in various ways including internet search such as in PubMed, Google Scholar, Ovid, INDMED and Google search. Manual search of articles were also done in library of the institution.

Keywords used for internet search were acute appendicitis, prediction, Modified Alvarado Score, New Adult Appendicitis Score, Appendicitis Inflammatory Response Score etc.,

2.1 History of appendicitis

Most of the history of appendicitis and appendectomy has been made during the past two centuries. Jacopo Berengario da Carpi gave the first description of this structure in 1522. Gabriele Fallopio, in 1561, appears to have been the first writer to compare the appendix to a worm. In1579 Caspar Bauhin proposed the ingenious theory that the appendix served in intrauterine life as a receptacle for the faexes. Many of anatomists added more or less insignificant ideas concerning the structure of the appendix and entered upon useless controversy concerning the name, function, position of the appendix vermiformis. The first successful appendectomy was performed in 1735 by Claudius Amyand. GeillaumeDupuytren considered that acute inflammation of the right side of the abdomen arose from disease of the caecum and not the appendix. As surgeons were wary of opening the abdomen for examination, early stages of appendicitis remained unknown. John Parkinson was able to give a good description of fatal appendicitis in 1812. Surgeons began draining localized abscesses which had already formed. [28]

2.2 Diagnosis of appendicitis

Charles McBurney (1889) was the first to attempt to make a diagnostic criterion for acute appendicitis by describing the McBurney's point. Clinically sometimes acute appendicitis becomes subject of a diagnostic dilemma in view of negative imaging evidence.

Clinical findings

Abdominal pain is the primary presenting complaint of patients with acute appendicitis. The diagnostic sequence of colicky central abdominal pain followed by vomiting with migration of the pain to the right iliac fossa is present in only 50% of patients. Typically, the patient describes a periumbilical colicky pain, which intensifies during the first 24 h, becoming constant and sharp, and migrates to the right iliac fossa. The initial pain represents a referred symptom resulting from the visceral innervation of the midgut, and the localized pain is caused by involvement of the parietal peritoneum after progression of the inflammatory process. Loss of appetite is often a predominant feature. Constipation and nausea with profuse vomiting may indicate development of generalized peritonitis after perforation but is rarely a major feature in simple appendicitis.[29]
Patients with acute appendicitis usually have a low-grade fever. Perforation should be suspected whenever the temperature exceeds 38.3 °C. If perforation does occur, periappendicealphlegmon or abscess will result if the terminal ileum, caecum, and omentum are able to "wall off" the inflammation. Peritonitis usually develops if there is free perforation into the abdominal cavity.[30-31]

Lab investigations

Laboratory data upon presentation usually reveal an elevated leukocytosis with a left shift. Neutrophilia greater than 75% will occur in the majority of cases. This is not true for elderly, immunocompromised patients, with conditions such as malignancy or AIDS; leukocytosis is observed in less than 15% of such patients. Measurement of C-reactive protein (CRP) is most likely to be elevated in appendicitis if symptoms are present for more than 12 hours.Interestingly, the combination of an elevated CRP, elevated WBC, or neutrophilia greater than 75% improves the sensitivity to 97%–100% for the diagnosis of acute appendicitis. Thus, for patients with normal values for all three studies, the likelihood of acute appendicitis would be low. The urinalysis is abnormal in 19%–40% of patients with acute appendicitis. Abnormalities include pyuria, bacteriuria, and haematuria.[29]

Imaging studies

Ultrasound (US)

US is rapid, non-invasive, inexpensive, and requires no patient preparation or contrast material administration. Although operator skill is an important factor in all US examinations, it has particular importance in the examination of the patient with right-lower-quadrant pain. In experienced hands, US has reported sensitivities of 75%–90%, specificities of 86%–95%, accuracies of 87%–96%, positive predictive values of 91%–94%, and negative predictive values of 89%–97% for the diagnosis of acute appendicitis. The appendix appears on ultrasound as a lamellated, elongated, blind-ending structure. Unlike normal bowel, the inflamed appendix is fixed, non-compressible, and appears round on transverse images. Measurements of appendix are performed with full compression. Traditionally, the diagnosis of appendicitis is made when the diameter of the compressed appendix exceeds 6 mm. In contrast, the thick-walled and non-compressible appendix, maintained in a fixed position by the compressing transducer, will show circumferential collar when inflamed. Appendicular perforation can be diagnosed when the appendix demonstrates irregular contour or when periappendiceal fluid collections are identified .[32-34]

ComputerizedTomography (CT)

CT represents an excellent diagnostic alternative for all other patients. CT is complementary to US and is recommended whenever US results are suboptimal, indeterminate, or normal in patients with acute abdominal pain. US is also complementary to CT and may be particularly useful in thin patients in whom the results of initial CT, no matter how it is performed, are equivocal. Analysis of the data for CT and US revealed higher sensitivity (96% *vs* 76%), accuracy (94% *vs* 83%), and negative predictive value (95% *vs* 76%) for CT.

Helical CT has reported sensitivities of 90%–98%, specificities of 91%–98%, accuracies of 94%–98%, positive predictive values of 92%–98%, and negative predictive values of 95%–98% for the diagnosis of acute appendicitis.

The inflamed appendix appears as an enlarged blind-ending tubular structure, frequently associated with inflammatory stranding in the surrounding fat. Traditionally, the threshold diameter of 6 mm was used for diagnosis of appendicitis. However, studies of healthy adults revealed that the normal range of appendicular size in an adult patient is 3–10 mm. Thus, using an appendicular threshold size of 9 mm is more accurate for diagnosis of appendicitis. The same radiographic image of faecal loading inside a dilated caecum may be visualized at CT in presence of acute appendicitis.

Magnetic resonance (MR)

MR imaging is emerging as an alternative to CT in pregnant patients and in patients who have an allergy to iodinated contrast material. MR imaging has a limited role in the work-up of suspected appendicitis.

Although the use of MR imaging avoids ionizing radiation, it has several disadvantages, including high cost, long duration of studies, and limited availability on an emergent basis. According to some authors, the use of MR imaging is limited to pregnant patients in whom ultrasound is inconclusive. On MR imaging, the appendix is identified as a tubular structure with intraluminal T1 and T2 prolongation. Appendicitis is diagnosed using thresholds of the size used for CT. Inflammatory changes are visualized as T2 hyperintensity in the periappendiceal fat.

There are no known adverse effects of MR imaging in human pregnancy, but the safety of MR imaging has not been proven unequivocally. Although tissue heating from radiofrequency pulses, acoustic stimulation potentially harm the fetus. It remains there for an indefinite amount of time, excreted by the fetal kidneys and subsequently swallowed by the fetus with amniotic fluid. Although there is no evidence of mutagenic or teratogenic effects of gadolinium in humans, mutagenic effects were seen in animal studies. Therefore a conservative approach avoids using gadolinium when possible in the first trimester.

Figure 2 Appendix on ultrasound

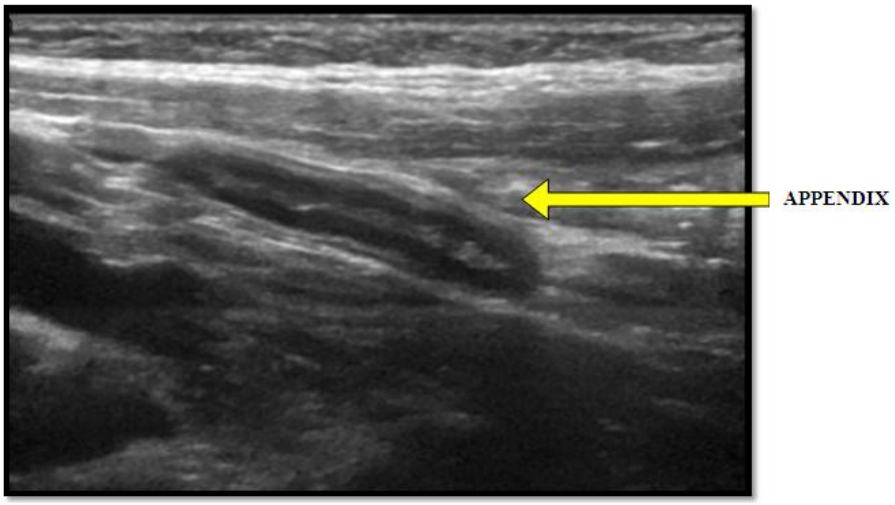


Figure 3 Appendix on computed tomography

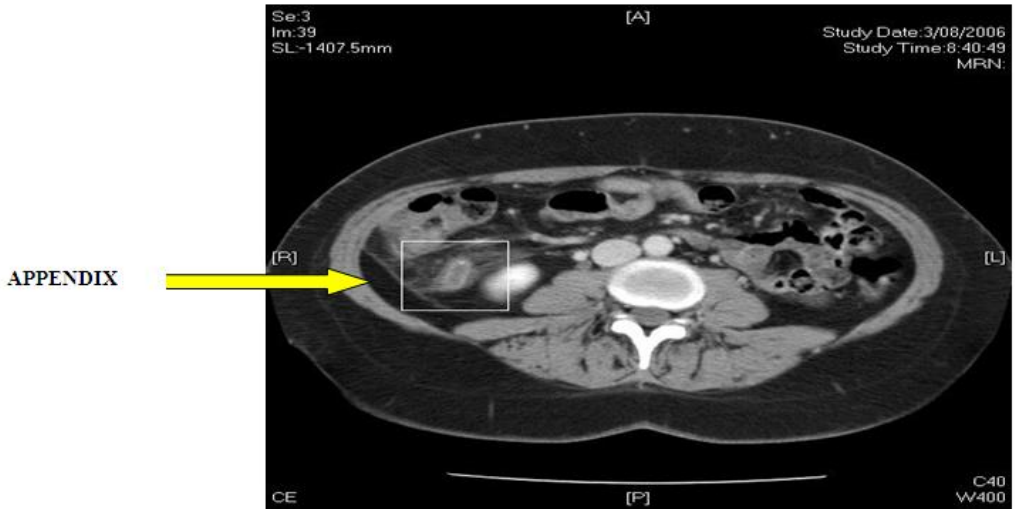
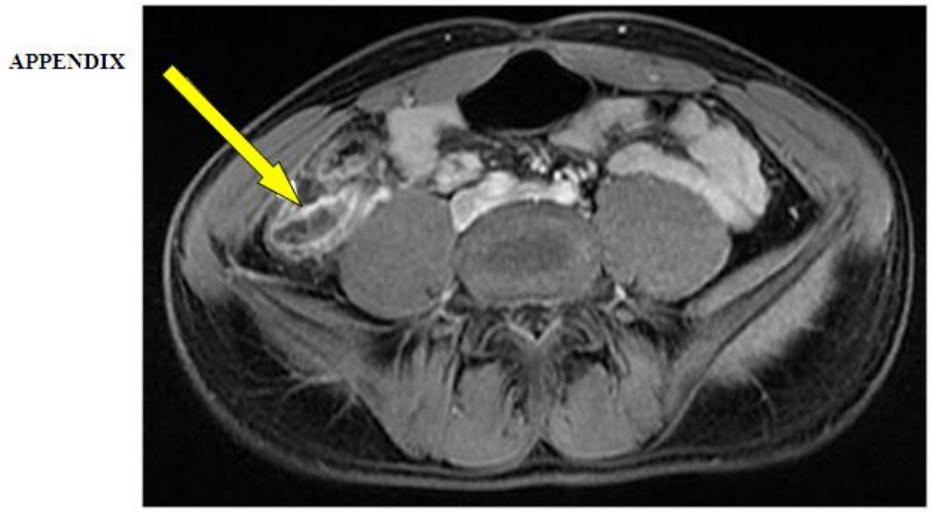


Figure 4 Appendix on magnetic resonance imaging



Scintigraphy

An inflamed bowel has strong chemotactic properties, and leukocytes actively invade the appendix in acute appendicitis. The migration and accumulation of radioactive leukocytes in the appendix is the basis for this study in patients believed to have acute appendicitis. Indium-111–labeled leukocyte scanning had a sensitivity of 86% and specificity of 93% for the diagnosis of acute appendicitis. Although the majority of these scans were performed at 2 h after injection, occasionally delayed images up to 17–24 h were required.

Technetium-99 m-albumin–colloid–labeled leukocyte (TAC-WBC) scanning appears to be superior to indium-111 because it is less expensive, requires shorter preparation time, requires less delay in time to positive scan (within 2 h), and has a lower radiation-absorbed dose, compared with indium-111. The overall sensitivity of this method is of 89% and its specificity is of 92%. It is not reliable in diagnosing appendicitis in women, with only 75% sensitivity and 43% positive predictive value in this subgroup. Limitations of radionuclide-labeled leukocyte scanning include cost, delay in diagnosis, exposure to radiation, relatively large percentage of indeterminate scans and decreased sensitivity and specificity in women.[35]

Alvarado score

The Alvarado score is a clinical scoring system used to stratify the risk of appendicitis in patients presenting with abdominal pain. Alvarado's original work was published in 1988 and is based on his retrospective data analysis of 305 patients presenting with abdominal pain suggestive of acute appendicitis. This study found eight predictive factors of diagnostic value in acute appendicitis and assigned each factor a value of 1 or 2 based on their diagnostic weight. A score of 1 was given for each of the following: elevated temperature >37.3°C, rebound tenderness, migration of pain to right lower quadrant (RLQ), anorexia, nausea or vomiting, and leukocyte left shift. A score of 2 was given for RLQ tenderness and leukocytosis >10 000. The likelihood of appendicitis and specific management recommendations are given based on the total score. A score of 5 or 6 is "compatible" with the diagnosis of acute appendicitis and recommends the clinician observe or serially examine the patient. A score of 7 or 8 is "probable" appendicitis and a score of 9 or 10 is "very probable" appendicitis and recommends surgical intervention.[15]

Ironically, the results in subsequent validation studies of the Alvarado score largely outperform the original study's findings and provide the major support for consideration of the rule in clinical practice. In a meta-analysis by Ohle et al. conducted in 2011, a review of 29 studies including 5,960 subjects revealed that for a cutoff of 5 (criteria to observe/ admit) there was a sensitivity of 99% (95% CI: 97-99%) and specificity of 43% (36-51%). At a cutoff of 7 (criteria to proceed directly to surgery) sensitivity was 82% (76-86%) and specificity was 81% (76-85%). Based on these results, the authors argue that using a cutoff score of 5 or lower provides a good "ruling out" score, while a cutoff of 7 is not sufficiently specific enough to provide an adequate "ruling in" score.[36]

However, several other smaller studies did not find such a high sensitivity. A 2007 retrospective study of 150 patients aged 7 and older who presented to the ED with abdominal pain found that 5% of patients with a score of 3 or less had appendicitis, as did 36% of patients with a score between 4-6. Similarly, in a retrospective study of 215 adults and children who presented with acute abdominal pain, Gwynn et al.1 found that 8.4% (12 of 143) of subjects with appendicitis had an Alvarado score below 5. Another retrospective study of 156

children found that 9% of subjects with complicated appendicitis would have been overlooked with the use of the Alvarado score.[37]

Alvarado score is the most well-known and best performing in validation studies, but it has some drawbacks. Its construction was based on a review of patients who had been operated with suspicion of appendicitis, whereas the score is supposed to be used on all patients with suspicion of appendicitis. Also, the score does not incorporate C-reactive protein as a variable, although many studies have shown the importance of C-reactive protein in the assessment of patients with appendicitis.[26]

Appendicitis inflammatory response (AIR) score

The recently introduced appendicitis inflammatory response (AIR) score was designed to overcome these drawbacks. This score incorporated the C-reactive protein value in its design and was developed and validated on a prospective cohort of patients with suspicion of acute appendicitis.[27]

This study externally validates that the AIR score has a high discriminating power and outperforms the Alvarado score. This score could aid in selecting patients who require timely surgery or those who require further evaluation. Finally, the score could safely avoid hospitalization and unneeded investigations in patients in whom the diagnosis is unlikely. Such a scoring system is important for future research to better compare results. But first, a proper prospective randomized controlled trial evaluating the effect of introducing such a score in a relevant patient population has to be performed.[38]

New Adult Appendicitis score (NAAS)

An ideal scoring system would work as a tool that speeds up and increases the accuracy of decision-making and at the same time reduces the need of potentially harmful and expensive imaging. Most of the existing diagnostic scores have the weakness of being originally based on retrospective data of patients with appendicitis, a small number of patients, or pediatric patients. In retrospective studies, a potential systematic bias involves ignoring the number and outcome of non-operated patients presenting with clinical suspicion of appendicitis. In children, in comparison to adults, the diagnostic limit of leukocyte count and differential diagnosis of acute abdominal pain vary, and depend on age. The difference to other scoring systems and the resulting improved diagnostic performance is based on well-known features of appendicitis; this score is the first to take into account the differences in diagnostics between sexes, and also the first to take into account the time passed between the onset of symptoms and taking the laboratory samples. In addition, strength of the new score is its being based on prospectively collected data of all patients with RLQ-pain, not only those operated on for suspected appendicitis.[23]

2.3 Articles review

A study was done **by Kollar D** et al (2015) to evaluate the AIR Score and compare its performance in predicting risk of appendicitis to both the Alvarado score and the clinical impression of a senior surgeon. All parameters included in the AIR and Alvarado scores as well as the initial clinical impression of a senior surgeon were prospectively recorded on patients referred to the surgical on call team with acute right iliac fossa pain over a 6-month period. Predictions were correlated with the final diagnosis of appendicitis.Appendicitis was the final diagnosis in 67 of 182 patients (37 %). The three methods of assessment stratified similar proportions (~40 %) of patients to a low probability of appendicitis ($p = 0.233$) with a false negative rate of <8 % that did not differ between the AIR score, Alvarado score or clinical assessment. The AIR score assigned a smaller proportion of patients to the high probability zone than the Alvarado score (14 vs. 45 %) but it did so with a substantially higher specificity (97 %) and positive predictive value (88 %) than the Alvarado score (76 and 65 %, respectively).The AIR score is accurate at excluding appendicitis in those deemed low risk and more accurate at predicting appendicitis than the Alvarado score in those deemed high risk. Its use as the basis for selective CT imaging in those deemed medium risk should be considered.[39]

A study was done by **Talukder D B** et al (2009) to evaluate the diagnostic accuracy of the modified Alvarado scoring system in clinical practice for acute appendicitis. A prospective study was conducted on 100 patients hospitalized with abdominal pain suggestive of acute appendicitis and were subsequently operated, from July 2005 to June 2008 at Bangladesh Rifles (BDR) hospital, Dhaka. Both male and female patients from 7 years to 55 years of age were enrolled in the study. Preoperatively, modified Alvarado score was assigned to all, and the results were compared with operative and histopathological diagnosis. Out of 100 operated patients 84 were diagnosed as a case of acute appendicitis on the basis of histopathological report. Patients with modified Alvarado score of 8-10, 5-7 and 1-4 have the accuracy of 95%, 78%, and 0% respectively. In the higher score group the accuracy is more and acceptable. Lower score group should be kept under observation. Score sensitivity is more in male than female patients. This scoring system is a reliable and practicable diagnostic modality to increase the accuracy in diagnosis of acute appendicitis and thus to minimize unnecessary appendicectomy.[40]

A study was done by **Öztürk A**et al (2015)to compare the effectiveness of computed tomography and Alvarado scoring system in the diagnosis of acute appendicitis in patients who underwent appendectomy with the preliminary diagnosis of acute appendicitis. One hundred and one patients who underwent appendectomy with the diagnosis of acute appendicitis between January and December 2011 were included in the study. Alvarado scores were calculated, and abdominal tomography scans were obtained for each patient before surgery. Patients with Alvarado score ≥7 were considered to have appendicitis while patients with a score <7 were considered not to have appendicitis. Patients were classified into two groups based on the presence of appendicitis findings on abdominal tomography. Histopathological examination of the appendices was performed following appendectomy. All patients were classified into groups according to pathology results, Alvarado score and tomography findings. The effectiveness of Alvarado score and tomography were compared using the McNemar test.Sixty patients (59.4%) were male and 41 (40.6%) were female, with a mean age of 32 years (5-85 years). The rate of negative appendectomy was 3.9%. In 78 patients (77.3%) the Alvarado score was ≥7, while 23 patients (22.7%) had Alvarado scores <7. The presence of appendicitis was determined by histopathology in 22 out of 23 patients whose Alvarado score was <7. Tomography indicated appendicitis in 97 patients (95.9%) whereas four patients (4.1%) exhibited no signs of appendicitis by tomography. However, histopathological evaluation indicated the presence of appendicitis in those four patients as well. The study results imply that tomography is a more effective means of diagnosing acute appendicitis as compared to the Alvarado scoring system.[41]

A study was done by **Scott A J** et al (2015). The potential benefits of risk stratification by the Appendicitis Inflammatory Response (AIR) score to guide clinical decision-making were assessed. During this 50-week prospective observational study at one institution, the AIR score was calculated for all patients admitted with suspected appendicitis. Appendicitis was diagnosed by histological examination, and patients were classified as having non-appendicitis pain if histological findings were negative or surgery was not performed. The diagnostic performance of the AIR score and the potential for risk stratification to reduce admissions, optimize imaging and prevent unnecessary explorations were quantified. A total of 464 patients were included, of whom 210 (63·3 per cent) with non-appendicitis pain were correctly classified as low risk. However, 13 low-risk patients had appendicitis. Low-risk patients accounted for 48·1 per cent of admissions (223 of 464), 57 per cent of negative explorations (48 of 84) and 50·7 per cent of imaging requests (149 of 294). An AIR score of 5 or more (intermediate and high risk) had high sensitivity for all severities of appendicitis (90 per cent) and also for advanced appendicitis (98 per cent). An AIR score of 9 or more (high risk) was very specific (97 per cent) for appendicitis, and the majority of patients with appendicitis in the high-risk group (21 of 30, 70 per cent) had perforation or gangrene. Ultrasound imaging could not exclude appendicitis in low-risk patients (negative likelihood ratio (LR) 1·0) but could rule-in the diagnosis in intermediate-risk patients (positive LR 10·2). CT could exclude appendicitis in low-risk patients (negative LR 0·0) and rule-in appendicitis in the intermediate group (positive LR 10·9).Risk stratification of patients with suspected appendicitis by the AIR score could guide decision-making to reduce admissions, optimize utility of diagnostic imaging and prevent negative explorations.[42]

A study was done by **Anderson** et al (2008) reported that the clinical diagnosis of appendicitis is a subjective synthesis of information from variables with ill-defined diagnostic value. This process could be improved by using a scoring system that includes objective variables that reflect the inflammatory response. This study describes the construction and evaluation of a new clinical appendicitis score. Data was collected prospectively from 545 patients admitted for suspected appendicitis at four hospitals. The score was constructed from eight variables with independent diagnostic value (right-lower-quadrant pain, rebound tenderness, muscular defense, WBC count, proportion neutrophils, CRP, body temperature, and vomiting) in 316 randomly selected patients and evaluated on the remaining 229 patients. Ordered logistic regression was used to obtain a high discriminating power with focus on advanced appendicitis. Diagnostic performance was compared with the Alvarado score. The ROC area of the new score was 0.97 for advanced appendicitis and 0.93 for all appendicitis compared with 0.92 ($p = 0.0027$) and 0.88 ($p = 0.0007$), respectively, for the Alvarado score. Sixty-three percent of the patients were classified into the low- or high-probability group with an accuracy of 97.2%, leaving 37% for further investigation. Seventy-three percent of the nonappendicitis patients, 67% of the advanced appendicitis, and 37% of all appendicitis patients were correctly classified into the low- and high-probability zone, respectively.This simple clinical score can correctly classify the majority of patients with suspected appendicitis, leaving the need for diagnostic imaging or diagnostic laparoscopy to the smaller group of patients with an indeterminate scoring result.[27]

A study was done by **Sammalkorpi** et al (2014)to construct a new scoring system for more accurate diagnostics of acute appendicitis. Applying the new score into clinical practice could reduce the need of potentially harmful diagnostic imaging. This prospective study enrolled 829 adults presenting with clinical suspicion of appendicitis, including 392 (47%) patients with appendicitis. The collected data included clinical findings and symptoms together with laboratory tests (white cell count, neutrophil count and C-reactive protein),

and the timing of the onset of symptoms. The score was constructed by logistic regression analysis using multiple imputations for missing values. Performance of the constructed score in patients with complete data (n = 725) was compared with Alvarado score and Appendicitis inflammatory response score. 343 (47%) of patients with complete data had appendicitis. 199 (58%) patients with appendicitis had score value at least 16 and were classified as high probability group with 93% specificity. Patients with score below 11 were classified as low probability of appendicitis. Only 4% of patients with appendicitis had a score below 11, and none of them had complicated appendicitis. In contrast, 207 (54%) of non-appendicitis patients had score below 11. There were no cases with complicated appendicitis in the low probability group. The area under ROC curve was significantly larger with the new score 0.882 (95% CI 0.858 – 0.906) compared with AUC of Alvarado score 0.790 (0.758 – 0.823) and Appendicitis inflammatory response score 0.810 (0.779 – 0.840). The new diagnostic score is fast and accurate in categorizing patients with suspected appendicitis, and roughly halves the need of diagnostic imaging.[23]

III. Aims& Objectives

To compare the diagnostic accuracy of modified Alvarado score, appendicitis inflammatory response score and new adult appendicitis score in patients with suspected acute appendicitis.

IV. Materials And Methods

4.1 Study design: The study was a prospective, cross sectional type of study. The study compared scores of patients presenting features of acute appendicitis.

4.2 Studysite:

The study was conducted in the Department of General Surgery, Tata Main Hospital, located in Jamshedpur of Jharkhand. This hospital is a 940 bedded multi-disciplinary hospital with specialties including pathology, radio diagnosis, orthopedics, surgery etc. The hospital includes 147 beds allotted exclusively to surgery department with 36 beds in High dependency unit. The Post-operative ward includes twenty-eight beds for post-operative observation and care.

4.3 Study population:

The study population constituted of patients presenting in the Department of General Surgery of Tata Main Hospital with features of acute appendicitis. The study participants who fulfilled inclusion criteria were included in the study.

4.3.1 Inclusion criteria:

1. Patients presenting to the surgical ward with signs and symptoms of acute appendicitis
2. Patients in age group between 12-65 years
3. Both sexes

4.3.2 Exclusion criteria:

1. Age less than 12 years and more than 65 years
2. Evidence of generalized peritonitis
3. Patient with past history of appendectomy
4. Patients with palpable lump in right iliac fossa
5. Patients suffering from Chronic Obstructive Pulmonary Disorders or ischemic heart disease.
6. Patients with known co-morbidities leading to raised CRP values

4.4 Study duration:

This study was carried out from April 2018 to April 2020

4.5 Sample size determination:

The total sample included three groups of study participants which were assessed with three scores. Sample size estimation with two means study –

In a study with research hypothesis viz .

Null hypothesis $H_0 : m_1 = m_2$ vs. Alternative hypothesis $H_a : m_1 = m_2 + d$

Where d is the difference between two means and n_1, n_2 ,and $n_3$are the sample size

for group – I , group – II group – III ,

$N = n_1 + n_2 + n_3$

Then the total sample size for the study is as follows

Where

Z_α is the normal deviate at a level of significance (Z_α IS 1.96 for 5% level of significance)
$Z_{1-\beta}$ is the normal deviate at (1- β)% power with β% of type II error (0.84 at 80% power of study)
$r = n_1 / n_2$ is the ratio of sample size required for 3 groups
δ is standard deviation ,d is difference of means of 3 groups .
The total sample size for the study with r = 1 (equal sample size)
The values are obtained from previous study .
Taking the α at 5% and desired power of study as 80%, Confidence level = 95% ,Confidence interval = 5%, Population = 150, Exclusion crit. = 30 and Sample size = 120
Therefore ,

$$N = \{(r + 1) (Z_{\alpha/2} + Z_{\beta/2})^2 \delta^2 \} / r d^2$$

$$N = (1+1) (1.96 + 0.84)^2 (0..47)^2 /1* (1.24 - 0.90)^2 = 29.96 \approx 30 \text{ (per group)}$$

The total sample size required for the study is 90
So, for the present study, 90 participants fulfilling the inclusion criteria were included.

4.6 Sampling method
The sampling method is consecutive sampling method done in Department of Surgery in the hospital. The study participant presenting with features of acute appendicitis whosoever fulfilled the inclusion criteria and willing to participate in the study were included successively.

4.7 Data collection techniques and tools
All the necessary information regarding the study was explained to the patients. Informed written consent was taken from the patients who were willing to participate in the study. After obtaining written informed consent in local vernacular language, the patients who were fulfilling the inclusion criteria were included in the study. Detailed history and clinical examination was done to establish proper diagnosis. In addition to routine investigations such as total leucocyte counts, serum electrolytes, serum creatinine, random blood sugar, CRP levels scores -Modified Alvarado score, Appendicitis Inflammatory Response score and New Adult Appendicitis score were calculated.

4.7.1 Parameters included in the study
Age, sex, registration number, occupation, CRP, BMI, diabetes, pain right lower quadrant, migratory pain, vomiting, high fever, leukocytosis, polymorphs, anorexia, rebound tenderness, guarding, modified Alvarado score, appendicitis inflammatory response score and new adult appendicitis score.

4.7.2 Follow up
Thereafter patients were followed up on an outpatient basis once a week for 30 days from the day of surgery.

4.8 Data Entry
All the data collected were entered in to a spread sheet on Micro-Soft Office Excel Sheet and later transferred to SPSS IBM version 21.0 for analysis. The data collection sheet was checked for completeness and correctness before entering into the worksheet. Data validation checks were performed at a regular interval for data entered into the worksheet of MS Excel.

4.9 Data analysis
Data analysis was done with Statistical Package for Social Sciences (SPSS IBM) version 21.0. Required univariate and bivariate analysis was done.

4.9.1 Univariate Analysis
The qualitative variables are described in the form of proportions and quantitative variables are described in the terms of mean, median, range and standard deviation.

4.9.2 Bivariate Analysis

Validation of modified Alvarado score, appendicitis inflammatory response score and new adult appendicitis score was done with Receiver Operating Characteristics (ROC) curve with calculation of sensitivity and specificity of the index.

4.10 Ethical permission
Ethical permission was obtained from ethics Committee for Post Graduate Studies, Tata Main Hospital.

4.11 Consent of the study participants

Printed consent form was given to the participants if she could read, or it was to read out to him the presence of another person, after which the participant was asked to sign (or place thumb impression) on the form.**(Annexure 2)**.The confidentiality of the study participants was maintained at all points of the study.

4.12 Scores used in the study

Table 2 Modified Alvarado score[25]

Clinical finding	Points
Migration of pain to the right lower quadrant	1
Anorexia	1
Nausea and vomiting	1
Tenderness in the right lower quadrant	2
Rebound pain	1
Elevated temperature more than 37.3	1
Leucocytosis (more than equal to 10,000 white blood cells per mm3)	2
Total	9

1-4 = no appendicitis,
5-6 = possible appendicitis,
7-8 = probable appendicitis
9 = definitive appendicitis

Table 3 Appendicitis inflammatory response score[27]

Clinical finding	Points
Vomiting	1
Pain in right lower quadrant	1
Rebound tenderness	
Light	1
Medium	2
Strong	3
Elevated temperature >38.5	1
Polymorphs	
70 – 84 %	1
>=85 %	2
WBC counts	
10 – 14.9 x 10^9/l	1
>15 x 10^9/l	2
CRP	
10 – 4.9 mg/l	1
>5.0 mg/l	2

sum 0–4 = low probability, outpatient follow up if unaltered general condition
sum 5–8 = indeterminate group, in-hospital active observation with rescoring/reimaging or diagnostic lap according to local traditions
sum 9–12 = high probability, surgical exploration is proposed

Table 4 New Adult appendicitis score[23]

Clinical finding	Points
Pain in right lower quadrant	2
Pain relocation	2
Right iliac fossa tenderness	3/1*
Right iliac fossa guarding	
Mild	2
Moderate or severe	4
Blood leucocyte count (x10^9)	
>=7.2 to <10.9	1
>=10.9 to <14	2
>=14	3
Polymorphs (%)	
>=62 to <75	2
>=75 to <83	3
>=83	4
CRP (mg/l) <24 hours	
>=4 to <11	2

>=11 to <25	3
>=25 to <83	5
>=83	1
CRP (mg/l) >24 hours	
>=12 to <53	2
>=53 to <152	2
>=152	1

*Men and women age 50+/women, age 16–49.
Probability of appendicitis:
high (≥16 points),
intermediate (11–15 points),
low (0–10 points)

V. Results

5.1 Profile of study participants

Among total 90 participants, 62(68.9%) were males and 28(31.1%) were females. The age of the study participants ranged from 12-65 years with mean (±SD) age was 32.14 (±8.90) years.

Among the study participants, 8(8.9%) were belonging to overweight and obese category as per Asian Indian classification of BMI. (Table 5)

Table 5 Profile of the study participants presented with acute abdomen. (N =90)

S.No.	Parameters	N (%)
1.	**Gender**	
	Male	62(68.9)
	Female	28(31.1)
2.	**BMI***	
	<18.5	23(25.6)
	18.5-22.9	39(43.3)
	23-24.9	20(22.2)
	>25	8(8.9)

***Asian Indian Classification of BMI

Figure 5 Distribution of study participants according to the gender. (N =90)

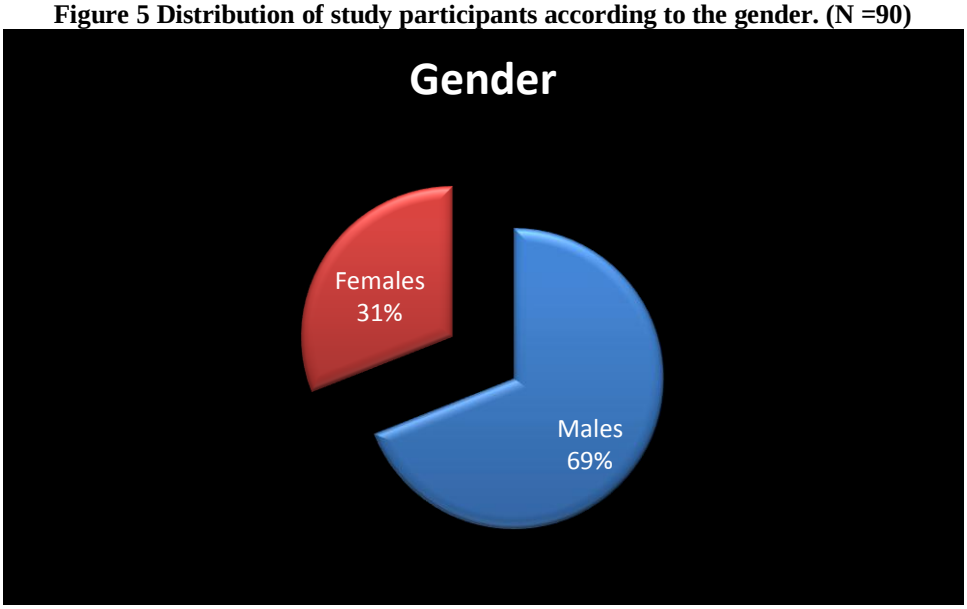
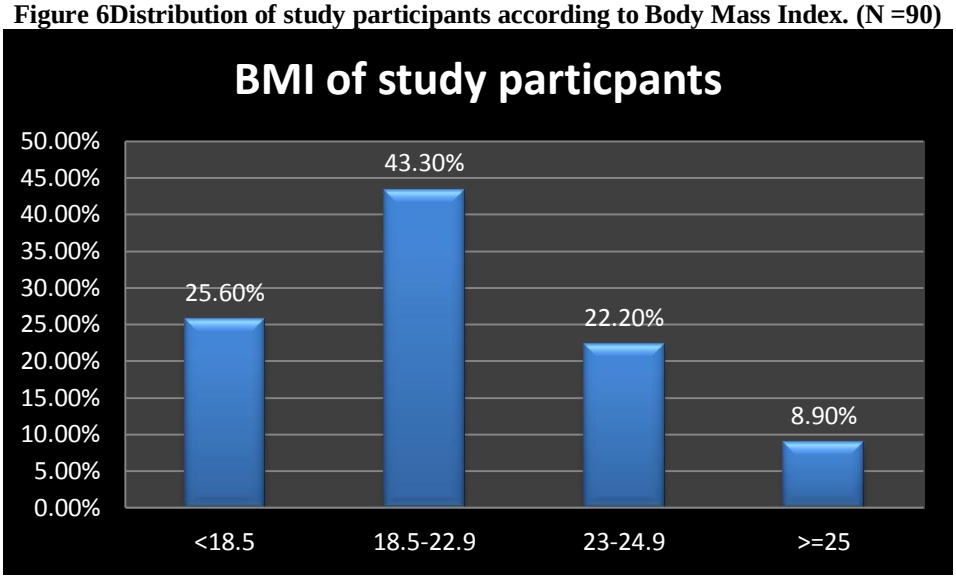


Figure 6Distribution of study participants according to Body Mass Index. (N =90)



5.2 Clinical presentation

The study participants presented with various symptoms –abdominal pain, nausea & vomiting, fever and migration of pain of which abdominal pain was reported by all the study participants 90(100%). Anorexia was observed in 16 (17.8%) participants. (Table 6)

Table 6 Distribution of study participants according to clinical symptoms. (N =90)

S.No.	Parameters	N(%)
1.	**Pain abdomen**	
	Present	90(100)
	Absent	0
2.	**Fever**	
	Present	14(15.6)
	Absent	76(84.4)
3.	**Nausea and vomiting**	
	Present	71(78.9)
	Absent	19(21.1)
4.	**Migration of pain**	
	Present	19(38)
	Absent	31(62)
5.	**Anorexia**	
	Yes	16(17.8)
	No	74(82.2)

On examination, guarding was seen in 32 (35.6%) of study population and rebound tenderness was seen among 7 (7.8%) of participants. (Table 7)

Table 7 Distribution of study participants according to clinical examination. (N =90)

S.No.	Parameters	N(%)
1.	**Guarding**	
	Mild	22(24.4)
	Moderate	8(8.9)
	Severe	2(2.2)
2.	**Right iliac fossa tenderness**	
	Present	88(97.8)
	Absent	2(2.2)
3.	**Rebound tenderness**	
	Light	3(3.3)
	Medium	2(2.2)
	Strong	2(2.2)

Table 8 Distribution of study participants according to medical history (N =90)

S. No.	Medical history	N(%)
1.	**Hypertension**	
	Yes	7(8)
	No	83(92)
2.	**Diabetes Mellitus**	
	Yes	14(15.5)

	No	76(84.5)
3.	**Liver disease and other systemic illness**	
	Yes	0
	No	90(100)

None of the study participants had history of liver disease or any other systemic illness. 4(8%) had history of hypertension and 14(15.5%) had history of diabetes.(Table 8)

5.3 Laboratory parameters

Laboratory parameters of the study participants are shown in the table 9.

Table 9 Distribution of study participants according to lab values (N =90)

S. No.	Parameters	N(%)
1.	**Leucocytes**	
	7000 to 11000	42(46.6)
	11000 to 14000	15(16.7)
	>14000	33(36.7)
2.	**Polymorphs**	
	62- 75 % neutrophils	48(53.3)
	75-83% neutrophils	9(10)
	>83 % neutrophils	33(36.7)
3.	**Body temperature**	
	≥38.5 C	14(15.6)
	< 38.5 C	76(84.4)
4.	**CRP levels in < 24 hours (mg/l)**	
	4 to 11	5(5.6)
	11 to 25	22(24.4)
	25 to 83	23(25.6)
	≥83	40(44.4)
5.	**CRP levels in >24 hours (mg/l)**	
	4 to 11	9(10)
	11 to 25	21(23.3)
	25 to 83	25(27.8)
	≥83	35(38.9)

Figure 7 Distribution of study participants according to Body temperature. (N =90)

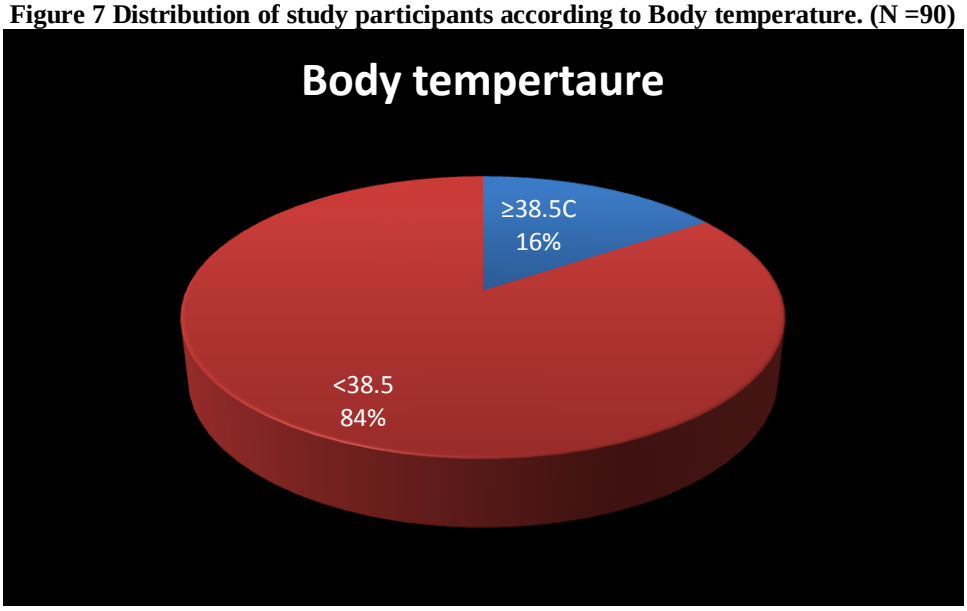
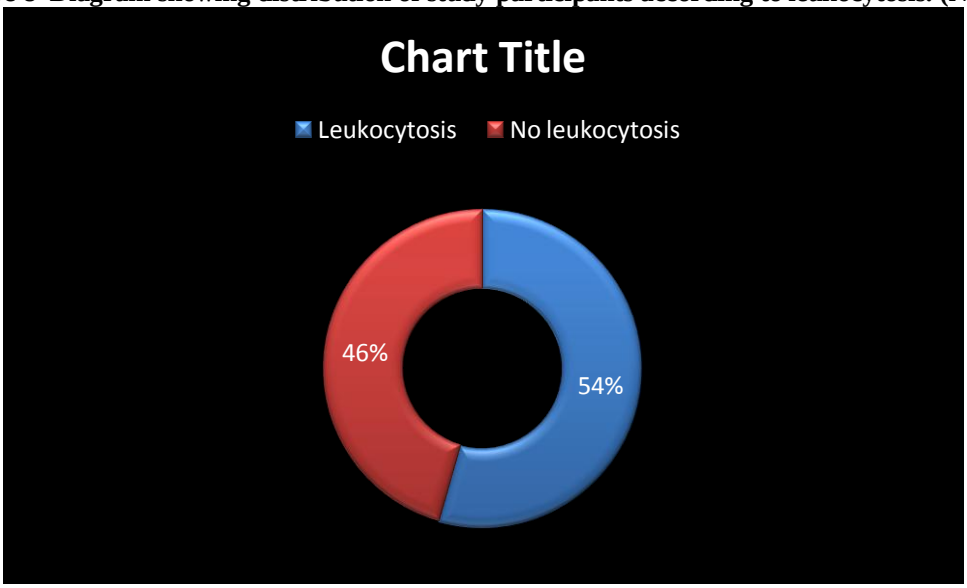


Figure 8 Diagram showing distribution of study participants according to leukocytosis. (N =90)



5.4 Scores

Modified Alvarado score

As per modified Alvarado score, definitive appendicitis was present in 58 (64.4%) participants Possible and probable appendicitis was seen among 25(27.8%) and 7 (7.8%) population respectively. (Table 10)

Table 10 Distribution of study participants according to Modified Alvarado score. (N =90)

Modified Alvarado score	N(%)
Modified Alvarado score	
1-4	0
5-6	7(7.8)
7-8	25(27.8)
9	58(64.4)

According to modified Alvarado score majority 83(92.2%) (Including definitive and possible) had appendicitis.

Appendicitis Inflammatory Response Score

As per Appendicitis Inflammatory Response Score (AIRS), indeterminate and high probability was seen among 39 (43.3%) and 47 (52.2%) respectively. Low probability of appendicitis was seen among 4 (4.4%) of study population (Table 11)

Appendicitis Inflammatory Response Score was able to predict 86 (95.6%) (scores 5-12) of study participants as having appendicitis.

Table 11Distribution of study participants according to Appendicitis Inflammatory Response Score. (N =90)

Appendicitis Inflammatory Response Score	N(%)
Appendicitis Inflammatory Response Score	
0–4	4(4.4)
5–8	39(43.3)
9–12	47(52.2)

New Adult Appendicitis Score

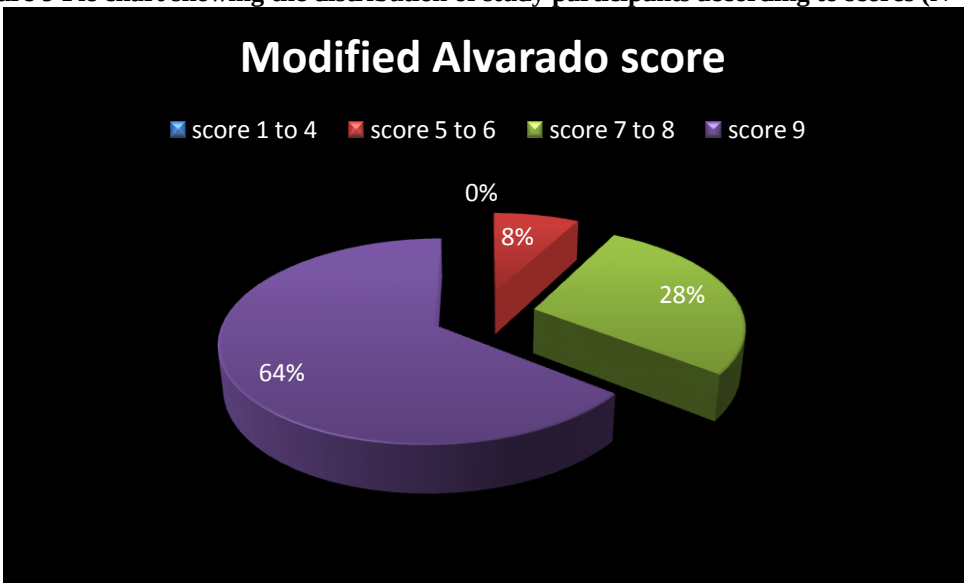
As per New Adult Appendicitis Score, 73 (81.1%) had higher probability of appendicitis. Intermediate probability was predicted among 17 (18.9%). (Table 12)

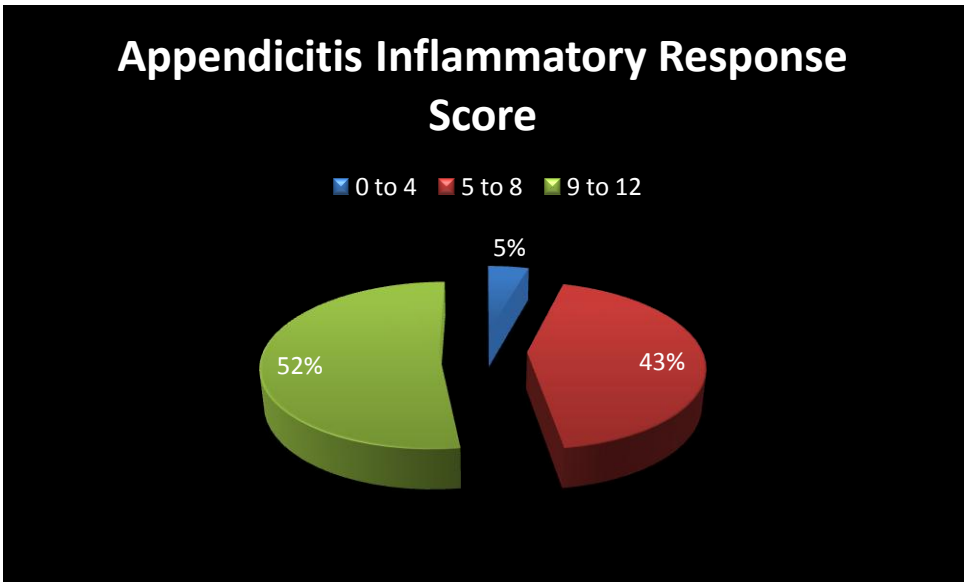
New Adult Appendicitis Score was able to predict all, 90 (100%) patients with appendicitis.(Including high and intermediate probability)

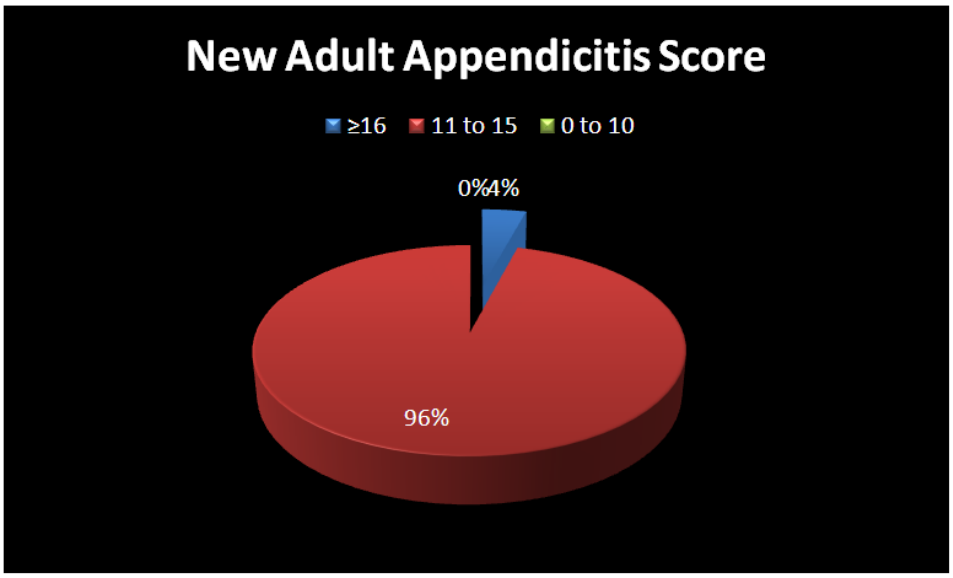
Table 12Distribution of study participants according to New Adult Appendicitis Score. (N =90)

New Adult Appendicitis Score	N(%)
New Adult Appendicitis Score	
High (≥16 points)	73(81.1)
Intermediate (11–15 points)	17(18.9)
Low (0–10 points)	0

Figure 9 Pie chart showing the distribution of study participants according to scores (N =90)

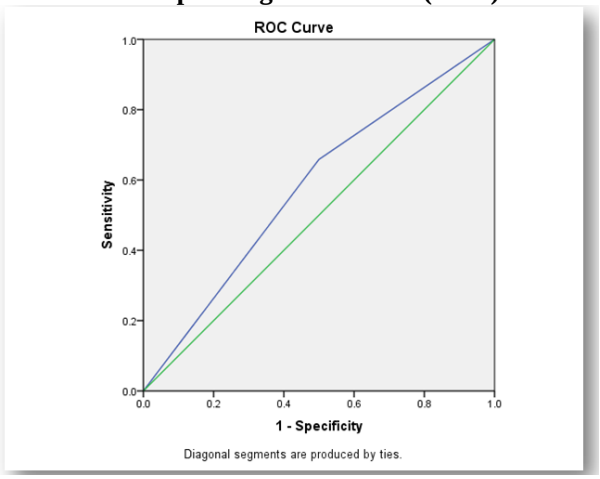




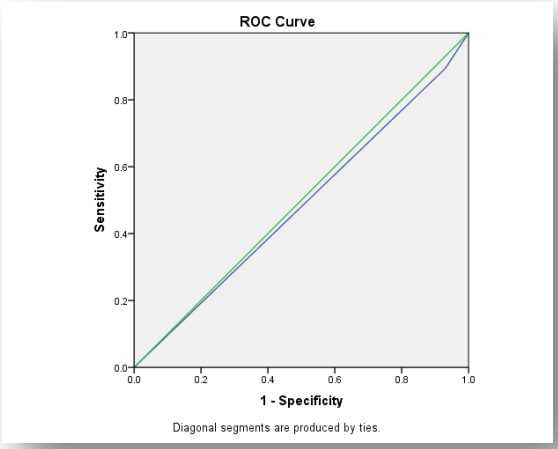


5.6 Prediction of appendicitis by scores

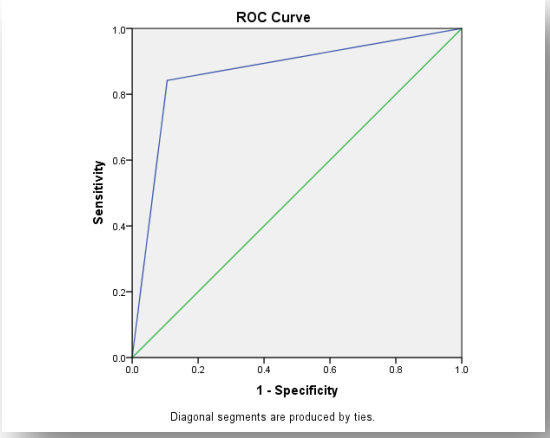
Figure 10 Receiver Operating Characteric (ROC) curve analysis



The area (95% CI) under the curve value is 0.528 (0.401-0.655) with a standard error value of 0.065. Modified Alvarado score was found to be a fair predictor as it predicted 53% who had appendicitis.



The area (95% CI) under the curve value is 0.482 (0.362-0.602) with a standard error value of 0.061. Appendicitis Inflammatory Response score was found to be poor predictor as it predicted 48 % who had appendicitis.



The area (95% CI) under the curve value is 0.868 (0.814-0.922) with a standard error value of 0.027. New Adult appendicitis score was found to be a better predictor as it predicted 87% who had appendicitis.

VI. Discussion

The present study was a cross sectional study done among 90 patients presented with features of acute appendicitis. Among total 90 participants, 62(68.9%) were males and 28(31.1%) were females. The age of the study participants ranged from 12-65 years with mean (±SD) age was 32.14 (±8.90) years.

Validation of scores

The predictive ability of Modified Alvarado score was 53%. This is much lower to previous study done by Talukhder D B et al which reported that Modified Alvarado scoring system is a reliable and practicable diagnostic modality to increase the accuracy in diagnosis of acute appendicitis and thus to minimize unnecessary appendicectomy.[40] However in a study done by OZturk A et al reported that Patients with Alvarado score ≥7 were considered to have appendicitis while patients with a score <7 were considered not to have appendicitis. In 78 patients (77.3%) the Alvarado score was ≥7, while 23 patients (22.7%) had Alvarado scores <7.[41]Our study used modified Alvarado score in which 92.2% were above score 7.

The predictive ability of Appendicitis Inflammatory Response Score was very poor (below 50%) in our study. In a previous study done by Kollar D et al[39] reported thatthe AIR score assigned a smaller proportion of patients to the high probability zone than the Alvarado score (14 vs. 45 %) but it did so with a substantially higher specificity (97 %) and positive predictive value (88 %) than the Alvarado score (76 and 65 %, respectively).

The predictive ability of New Adult Appendicitis score was 87% with area under the curve value of 0.868 (0.814-0.922). This finding is similar to previous study report bySammalkorpi et al et al which reported that area under ROC curve was significantly larger with the new score 0.882 (95% CI 0.858 – 0.906).[23]

VII. Conclusion

- Among the three scores- modified Alvarado score, Appendicitis Inflammatory Response score and New Adult Appendicitis score, New Adult appendicitis score was found to be a better predictor as it predicted appendicitis in 87% patients in study group.
- Appendicitis Inflammatory Response score with a cut off of >8 predicted 95.6% and was proven to be a good predictor if the score is >8.
- Modified Alvarado score was found to be a fair predictor as it predicted 53% who had appendicitis, however those who got a modified Alvarado score >7 was 92.2% which again justifies that score >7 as a cut off in predicting acute appendicitis.

VIII. Recommendations

- The New Adult Appendicitis Score is more accurate in predicting the diagnosis of acute appendicitis. As the proportion of patients who were diagnosed as acute appendicitis with NAAS and underwent appendectomy and had appendicitis is significantly higher and so it can be safely used as diagnostic score in diagnosing acute appendicitis over other two scores.
- CRP plays an important role in accurately diagnosing acute appendicitis especially the values within 24 hours and after 24 hours.

IX. Summary

- The objective of the study was to compare the diagnostic accuracy of modified Alvarado score, appendicitis inflammatory response score and new adult appendicitis score in patients with suspected acute appendicitis.
- The study was a prospective, cross sectional type of study. The study compared scores of patients presenting features of acute appendicitis.
- The study population constituted of patients presenting in the Department of General Surgery of Tata Main Hospital with features of acute appendicitis. The study participants who fulfilled inclusion criteria were included in the study.
- The total sample size required for the study is 90. So, for the present study, 90 participants fulfilling the inclusion criteria were included.
- The sampling method is consecutive sampling method done in Department of Surgery in the hospital.
- Validation of modified Alvarado score, appendicitis inflammatory response score and new adult appendicitis score was done with Receiver Operating Characteristics (ROC) curve with calculation of sensitivity and specificity of the index.
- Among total 90 participants, 62(68.9%) were males and 28(31.1%) were females. The age of the study participants ranged from 19-67 years with mean (±SD) age was 42.1 (±11.7) years.

- Among the study participants, 8(8.9%) were belonging to overweight and obese category as per Asian Indian classification of BMI. Only 61(67.3%) of study participants appear normally nourished.
- The study participants presented with various symptoms –abdominal pain, nausea & vomiting, fever and migration of pain of which abdominal pain was reported by all the study participants 90(100%). Anorexia was observed in 16 (17.8%) participants.
- On examination, guarding was seen in 32 (35.6%) of study population and rebound tenderness was seen among 7 (7.8%) of participants.
- As per modified Alvarado score, definitive appendicitis was present in 58 (64.4%) participants Possible and probable appendicitis was seen among 25(27.8%) and 7 (7.8%) population respectively. According to modified Alvarado score majority 83(92.2%) (including definitive and possible) had appendicitis.
- As per Appendicitis Inflammatory Response Score (AIRS), indeterminate and high probability was seen among 39 (43.3%) and 47 (52.2%) respectively. Low probability of appendicitis was seen among 4 (4.4%) of study population Appendicitis Inflammatory Response Score was able to predict 86 (95.6%) (scores 5-12) of study participants as having appendicitis.
- As per New Adult Appendicitis Score, 73 (81.1%) had higher probability of appendicitis. Intermediate probability was predicted among 17 (18.9%).New Adult Appendicitis Score was able to predict all, 90 (100%) patients with appendicitis.(Including high and intermediate probability)
- Modified Alvarado score was found to be a fair predictor as it predicted 53% who had appendicitis. The area (95% CI) under the curve value is 0.528 (0.401-0.655) with a standard error value of 0.065.
- Appendicitis Inflammatory Response score was found to be poor predictor as it predicted 48 % who had appendicitis. The area (95% CI) under the curve value is 0.482 (0.362-0.602) with a standard error value of 0.061.
- New Ault appendicitis score was found to be a better predictor as it predicted 87% who had appendicitis. The area (95% CI) under the curve value is 0.868 (0.814-0.922) with a standard error value of 0.027.
- Among the three scores- modified Alvarado score, Appendicitis Inflammatory Response score and New Ault appendicitis score, New Ault appendicitis score was found to be a better predictor as it predicted 87% who had appendicitis.
- Appendicitis Inflammatory Response score with a cut off of >8 it predicted 95.6% and it was proven to be a good predictor if the score is >8.
- Modified Alvarado score was found to be a fair predictor as it predicted 53% who had appendicitis, however those who got a modified Alvarado score >7 was 92.2% which again justifies that score >7 as a cut off in predicting acute appendicitis.

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