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The Jumping Up (J-Up) Test: Making the Diagnosis of Acute Appendicitis Easier in Children

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Abstract

We evaluate a new clinical test, jumping up (J-up) test, to diagnose easier appendicitis in children. A total of 407 patients, aged 5 to16 years, with right lower quadrant abdominal pain were asked to jump rising both hands and trying to reach a toy hanging down from the ceiling of the examination room. Bieri pediatric Face Pain Scale was used for recording the pain response. J-up test has sensitivity of 87% and specificity of 70%. A positive J-up test combined with leukocytosis (white blood cells count $>$12 000/mm^3), neutrophilia $>$75%, neutrophil/lymphocyte $>$2, and C-reactive protein $>$5 mg/dL, achieved a posttest probability of appendicitis of 85%. A negative J-up test combined with the aforementioned blood markers within normal range had a posttest probability for non-appendicitis of 92%. J-up test is a reliable clinical test, which could be used even by an inexperienced doctor. Combined with classical blood markers, it could successfully predict which child is in urgent need or not of surgery.

Keywords

appendicitis in children, Pediatric Pain Face Scale, peritonism, clinical test, right lower quadrant (RLQ) pain

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Introduction

Acute appendicitis is one of the most common emergency conditions for pediatric care practitioners. More than 5% to 17% of patients with appendicitis are misdiagnosed as having a nonspecific abdominal pain and readmitted with a life-threatening condition such as abdominal abscess, diffuse peritonitis, or even sepsis. On the other hand, many children are operated yearly with a preoperative diagnosis of acute appendicitis, but 8.6% of them constitute the so-called "negative appendectomies."[1,2]

Appendicitis in children remains a diagnostic dilemma because the symptoms and signs are not specific, mimicking a plead of pathology.[3] The diagnostic process must direct to an answer on what is going on with a crying child who sometimes cannot express himself/herself verbally and cannot answer even simple questions such as where exactly the pain is located. To reach a correct diagnosis, clinical examination, several laboratory tests, and imaging studies are used.[4,5] The diagnosis commonly demands surgical consultation, hospital stay, and sometimes advanced computed tomography (CT) imaging studies when the clinical evidence is not pathognomonic for the disease.[6,7]

Peritonism is a clinical sign that is the most decisive for an appendectomy in patients with right lower quadrant (RLQ) abdominal pain. Numerous clinical ways to demonstrate peritonism in children and adults have been reported, but to evoke the sign in children remains elusive because it requires good clinical skills and many years of intensive training to recognize the acute abdomen.[8] Rebound tenderness and guarding have poor interrater reliability in children, whereas pain on walking, coughing, and jumping is a physical finding with a moderate agreement between examiners. That sign is included in

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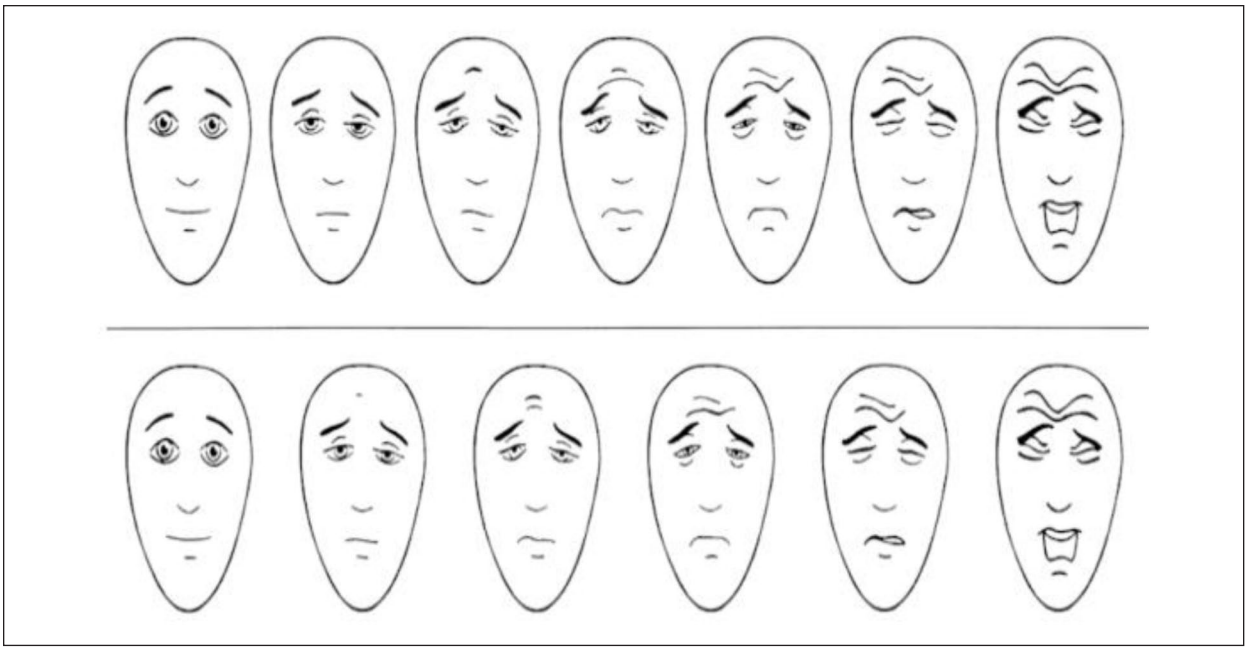

Figure 1. Bieri faces scale pain in children.

Pediatric Appendicitis Score but clinicians are not accustomed to eliciting it.[9]

To overcome clinical misinterpretations, several face pain scales have been reported for evaluating the facial expression as a clinical sign of pediatric pain. The widespread acceptance of face pain scales has likely been facilitated by the importance of facial expression in the clinical communication of pain. Therefore, the accuracy of physical examination in patients with RLQ abdominal pain could be enhanced by a clinical test that incorporates a pain face scale for a subjective interpretation of peritonism.[10-13]

Materials and Methods

During the year 2017-2018, 437 children, aged 5 to 16 years, with RLQ abdominal pain up to 6 hours duration were evaluated prospectively in our pediatric emergency surgical department. Excluded were 30 patients operated for appendicitis in the past, patients with malignancies, those on corticosteroids, and those with chronic diseases, such as diabetes, inflammatory bowel disease, or mental diseases. The remaining 407 patients were eligible and enrolled in this study.

A new clinical test was introduced during the physical examination, the Jumping up (J-up) test. Every patient with RLQ abdominal pain was asked to jump and try to reach with both rising hands a toy hanging down from the ceiling of the examination room. The face expression of each child was noted. The Bieri et al face scale for pediatric pain was used to evaluate the findings (Figure 1). A Bieri scale face 1 expression due to pain was interpreted as a positive sign of peritonism in children older than 10 years of age, and a face 2 expression was recorded as a positive sign in children younger than 10 years of age. This was considered more appropriate for younger children because they react facially to pain more than the older children. Our main assumption was that a combination of vibration and stretching of the whole body of the patient would bring out profoundly a facial response to pain by an irritated peritoneum. During the test, mild mechanical stress imposed on an inflamed peritoneum would involuntarily elicit a pain face expression that could be objectively recorded as a positive or negative sign of peritonism. We also considered as positive a body pain response, such as crying and stopping the J-up test or bending forward and holding the abdomen during the procedure.

All eligible patients with acute RLQ abdominal pain admitted to the emergency surgical department were evaluated clinically by an assigned pediatric surgery resident who qualified the J-up test as positive or negative. An ultrasound scan of the appendix was performed by staff radiologists at the discretion of the staff pediatric surgeon blinded to the results of the J-up test. The decision to operate or not a patient with RLQ abdominal pain was made by staff pediatric surgeons also blinded to the results of the J-up test. All appendixes were histologically confirmed. Follow-up of the nonoperated patients was done by a telephone interview with their

caregivers after 10 days of their registration. Children who returned to their normal activities free of symptoms were considered as non-appendicitis cases.

We constructed contingency 2 × 2 tables and calculated sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), positive likelihood ratio (LR+), negative likelihood ratio (LR−), pretest odds, posttest odds, posttest probability of having appendicitis after a positive (PTP +ve) and a negative (PTP −ve) J-up test, leukocytosis, neutrophilia (NE), the neutrophil/lymphocyte (NE/LY) ratio >2, and C-reactive protein >5 mg/dL. We also identified the J-up profiles that achieved the highest and lowest risk of appendicitis. Based on these PTPs, we stratified our patients into groups by highest, intermediate, and lowest risk profiles.

The baseline characteristics were analyzed using descriptive statistics. Continuous variables were tested for normality using the Shapiro-Wilk test. Group differences between appendicitis and non-appendicitis groups were tested using the Mann-Whitney *U* test. Nonnormally distributed continuous data were expressed as the median and interquartile range. Two-tailed Fisher's exact test was used to test significance in contingency tables. Statistical values were considered significant at a cutoff point of .05. For statistical analysis, Medicalc software was used.[14,15]

This study was approved by the Committee of Research Affairs of "P & A Kyriakou" Children's Hospital. Informed consent was obtained from the caregivers of the patients.

Results

The characteristics of the patients are presented in Tables 1 and 2.

The sensitivity and specificity of a positive J-up test for appendicitis was 87% and 70%, respectively. The PPV of the J-up test was 71% and the NPV was 86%. The LR+ was 2.85 and the LR− was 0.19. The sensitivity of leukocytosis (white blood cell count [WBC] >12 000/mm^3) was 72%, the specificity was 72%, the PPV was 69%, the NPV was 76%, the LR+ was 2.56, and the LR− was 0.39. The sensitivity and specificity of NE (defined as neutrophils >75% of WBC count) were 67% and 72%, respectively; the PPV was 68%, the NPV was 72%, the LR+ was 2.44, and the LR− was 0.45. The NE/LY ratio >2 had a sensitivity of 92%, specificity of 43%, PPV of 58%, NPV of 86%, LR+ of 1.61, and LR− of 0.18. The C-reactive protein (CRP) >5 mg/L had a sensitivity of 60%, specificity of 71%, PPV of 64%, NPV of 66%, LR+ of 2.03, and LR− of 0.58.

Table 1. The final diagnosis in 407 patients with RLQ abdominal pain.

Diagnosis	n	%
Appendicitis	190	46.68
Mesenteric lymphadenitis	69	16.95
Nonspecific abdominal pain	68	16.70
Viral enteritis	54	13.26
Urinary tract infection	10	2.45
Terminal ileitis	6	1.47
Ovarian cyst with torsion	2	0.49
Ovarian cyst without torsion	1	0.24
Meckel's diverticulum	2	0.49
Pelvic inflammatory disease	2	0.49
Fallopian tube torsion	1	0.24
Carcinoid tumor of appendix	1	0.24
Intrauterine pregnancy	1	0.24
Total	407	100

Ultrasound scan (US) was performed by radiologists in 118 (29%) cases. In 16 (13.56%) cases, the appendix was not or partially visualized. Of the remaining 102 cases, 56 (54.9%) were positive and 46 (45.10%) were negative for appendicitis. Histology confirmed appendicitis in 47 positive US and non-appendicitis in 44 negative US. US had a sensitivity of 95.9% (87.4-99.3), specificity of 83% (75.2-86.1), PPV of 83.9% (76.5-86.9), NPV of 95.7% (86.6-99.2), LR+ of 5.65 (3.11-10), and LR− of 0.05 (0.01-0.19).

As estimated, the pretest probability of having acute appendicitis was 46.7%. After a positive J-up test, the probability of having appendicitis (PTP-APP) was 71.42%, and after a negative J-up test, the probability of not having appendicitis (PTP-NO-APP) was 86%. The PTP-APP after a positive J-up test plus leukocytosis was 77%. The PTP-NO-APP of its "mirror" negative J-up plus no leukocytosis was 90%. The PTP-APP after a combination of a positive J-up test and leukocytosis plus NE >75% was approximately 84%. Patients with a negative J-up test, no leukocytosis, and no NE had a PTP-NO-APP of 90%. Patients with a combined profile of positive J-up test, leukocytosis, NE, and NE/LY >2 had PTP-APP of 85%. Patients with a "mirror" combined profile of negative J-up test, no leukocytosis, no NE, and NE/LY ≤2 had PTP-NO-APP of 90%. The "all positive" profile of patients with a positive J-up test combined by leukocytosis, NE, NE/LY>2, and CRP >5 mg/L had PTP-APP of 85%. The "all negative" profile of patients with a negative J-up test and all the 4 blood markers negative had PTP-APP of 8% and PTP-NO-APP of 92%. The PTP-APP after the positive US was 84%, and after the negative US, the PTP-APP was 4%, and the PTP-NO APP was 96%.

Table 2. Characteristics of 407 patients with RLQ abdominal pain.

Parameter	Appendicitis, N = 190 (46.7%), n (%)	No Appendicitis, N = 217 (53.3%), n (%)	Total, N = 407 (100%), n (%)	*P*
Male	110 (57.89)	103 (47.46)	213 (52.33)	.0373
Laparotomy/laparoscopy	190 (100)	14 (6.45)	204 (50.12)	<.000001
RLQ tenderness	189 (99.47)	199 (91.70)	388 (95.33)	.000092
J-up negative	25 (13.15)	151 (69.58)	176 (43.24)	<.000001
J-up positive	165 (86.84)	66 (30.41)	231 (56.76)	<.000001
White blood cells count >12 000/mm^3	137 (72.10)	61 (28.11)	198 (48.65)	<.000001
Neutrophils >75%	128 (67.37)	60 (27.65)	188 (46.19)	.000001
Neutrophils/lymphocytes ratio >2	175 (92.10)	123 (56.68)	298 (73.22)	<.000001
CRP >5 mg/dL	112 (58.95)	63 (29.03)	175 (43)	<.000001
J-up positive white blood cells count >12 000/mm^3	124 (65.26)	29 (13.36)	153 (37.59)	<.000001
J-up positive white blood cells count >12 000/mm^3, neutrophils >75%	102 (53.68)	19 (8.76)	121 (29.73)	<.000001
J-up positive white blood cells count >12 000/mm^3, neutrophils >75%, neutrophils/lymphocytes ratio >2	101 (53.15)	18 (8.29)	119 (29.24)	<.000001
J-up positive white blood cells count >12 000/mm^3, neutrophils >75%, neutrophils/lymphocytes ratio >2, CRP >5 mg/dL	58 (30.53)	11 (5.07)	68 (16.70)	<.000001

Abbreviations: RLQ, right lower quadrant; J-up; Jumping-up test; CRP, C-reactive protein.

The relative frequency of the highest risk J-up profile patients was 16.5% (67/407). A total of 89.5% of these patients were surgically treated. In 5% of them, a histological examination of the appendix was normal (3 false-positive cases). One case of these false positives had Meckel's diverticulum and one pelvic inflammatory disease. The highest J-up risk profile for an "urgent-acute appendicitis" diagnosis had a sensitivity of 30%, a specificity of 95.4%, PPV of 85%, NPV of 61%, LR+ of 6.5, and LR− of 0.73. The lowest J-up risk profile had a relative frequency of 15% (61/407) and for a "not urgent-no appendicitis" diagnosis yielded a sensitivity of 26%, a specificity of 97.4%, PPV of 92%, NPV of 53.6%, LR+ of 10, and LR− of 0.76. The lowest risk J-up profile did not identify appendicitis in 5 cases. Histological examination in those cases identified simple, noncomplicated appendicitis.

A stratification of the patients into groups according to their J-up risk profile, their relative frequencies, and postoperative diagnosis is presented in Table 3. The highest and lowest risk profiles additively had a relative frequency of 31.7% and a negative appendectomy rate of 3.1%. The lowest J-up risk profile failed to detect 5 appendicitis cases. The highest J-up risk profile had 3 false-positive cases: one case had a pelvic inflammatory disease. The rest had normal histological findings. The intermediate-risk J-up profile had the highest relative frequency of 68.31% (278/407) and a relative negative appendectomy rate of 3.59% (10 false-positive cases).

A κ-statistic (chance-adjusted agreement), the overall percent agreement (OPCA), the positive partial agreement (PPA), the negative partial agreement (NPA) between the highest-lowest J-up risk profiles and the staff pediatric surgeon's decision to operate or not were calculated. On the decision to operate or not a patient with RLQ abdominal pain, there was a good to excellent agreement with a κ-statistic of 0.798 (95% confidence interval [95%] = 0.604-0.902), a high OPCA (89.92%), a high PPA (89.55%), and a high NPA (90.32%) between the staff pediatric surgeons and the J-up risk profiles.

A κ-statistic, the OPCA, the PPA, the NPA between the highest-lowest J-up risk profiles, and the "gold standard" ultrasound diagnosis were also calculated. There was a good to excellent agreement with a κ-statistic of 0.624 (95% CI = 0.252-0.956), a high OPCA (81.81%), a high PPA (84.61%), and a high NPA (77.8%) between the J-up profiles and the ultrasound diagnosis.

Discussion

Demonstration of peritonism in patients with RLQ abdominal pain has low diagnostic accuracy but as a physical sign remains the mainstay of clinical diagnosis of appendicitis. However, bringing out the sign of peritonism underlies examiner bias and some other

Table 3. J-up risk profiles of appendicitis and postoperative diagnosis.

J-up Risk Profiles and Pathology Diagnosis	n (%)	Appendectomy/ Appendicitis, n (%)	Complicated Appendicitis (Gangrenous With or Without Rupture), n (%)	Appendectomy/No Appendicitis (Negative Appendectomies), n (%)
Lowest risk	62/407 (15.23)	5/62 (8.06)	0/5 (0.00)	1/6[a] (16.67)
Intermediate risk	278/407 (68.31)	128/278 (46.04)	77/128 (60.15)	10/138[b] (7.25)
Highest risk	67/407 (16.46)	57/67 (85.07)	45/57 (78.94)	3/60[c] (5)
Total	407 (100)	190/407 (46.68)	122/190 (64.21)	14/204 (6.86)

[a]One case of carcinoid tumor of the appendix.
[b]One case of Meckel's diverticulum, 1 case of ovary cyst with torsion.
[c]One case of pelvic inflammatory disease.

unique challenges that necessitate consideration of the child's age, developmental level, cognitive, and communication skills.[1,9] For example, touching a child's abdomen that is in pain may raise anxiety and often leads to generalized guarding. Crying and noncooperative behavior of a preschool-aged child could promote a false impression of generalized guarding of the abdomen. On the other hand, children older than 10 years and adolescents tend to minimize or deny the pain.[12,16-19]

The J-up test is an active distraction maneuver to overcome the patient's examination distress. At the same time, it provokes a mild vibration and stretching to the peritoneum evoking a facial expression that can be objectively recorded. To record a face expression of peritonism, we used Bieri et al face pain scale and qualify the J-up test as positive or negative. We have noticed that even for the noncooperative children, the J-up test is very easy to perform. Patients are actively distracted and find the test even amusing as some of them smile or laugh during the J-up process. Contrariwise, they avoid continuing and either stop or bend forward holding their abdomen if J-up disturbs them.

The results of our study showed that the J-up test for acute appendicitis had a sensitivity of 87%, a specificity of 70%, LR+ approximately of 3 (95% CI = 2.39-3.35), and LR− of 0.2 (95% CI = 0.13-0.27). Pooled data analysis of 7 studies in children suspected for appendicitis reported that clinical signs of peritonism, such as rebound tenderness, had a LR+ of 2.19 (95% CI = 1.91-2.51), guarding had LR+ of 2.09 (95% CI = 1.84-2.37), while pain with coughing/whooping had LR+ of 1.61 (95% CI = 1.42-1.83) and LR− of 0.52 (95% CI = 0.45-0.61) for appendicitis. These results highlight the variability in eliciting physical findings of peritonism in children. Agreement between different examiners on clinical signs of appendicitis such as rebound tenderness, guarding, and pain on walking/hoping is only of moderate degree. This may limit the reproducibility of physical findings of peritonism. We avoided interrater variability between examiners having the J-up test conducted by only one examiner, the author of this study.[20,21]

Common laboratory test values including WBC count, neutrophils, a shift to left NE/LY ratio, and CRP levels have been associated with appendicitis. However, each laboratory test value is not strongly discriminatory and predictive for acute appendicitis. In children with RLQ abdominal pain LR+ of CRP levels greater than 5mg/dL was 2.1 (95% CI = 1.61-2.76), of WBC count $>12\,000/mm^3$ and NE >75% LR+ was 2.02 (95% CI = 1.85-2.21), and LR− 0.35 (95% CI = 0.28-0.43). Our findings of estimated LR+ and LR− are in agreement with a meta-analysis that concluded that common laboratory test values cannot be individually relied on to rule appendicitis.[20,21]

On the other hand, combining laboratory findings with clinical features, such as peritonism, may lead to even better accuracy for appendicitis. According to a meta-analysis, the greatest discriminators and predictors of acute appendicitis included rebound tenderness or guarding combined with a WBC count $\geq 10\,000/mm^3$. The LR+ of both of these variables was 11.34 (95% CI = 6.65-19.56) and the LR− 0.14 (95% CI = 0.08-0.24). It has been mentioned that meta-analysis should be interpreted with caution due to the large heterogeneity of the pooled accuracy estimates.[20]

In our study, we estimated that patients with a positive J-up test had a 71.45% PTP that cannot rule in appendicitis with certainty. We combined J-up test with 4 common laboratory blood markers of inflammation. Patients with a positive J-up test with leukocytosis, NE, NE/LY ratio >2, and CRP >5mg/dL had a LR+ of 6.51 (95% CI = 3.36-13.30) and a LH− of 0.73 (95% CI = 0.69-0.80). This J-up profile raises PTP-APP from 46.7% to 85%. This is very close to being pathognomonic for the disorder. We have estimated that a risk profile with PTP-APP of 85% in real clinical situations needed surgery for appendicitis in 85% of its cases. Thus, the PTP-NO-APP in patients with a negative J-up test combined with these 4 blood markers negative was

92%. This PTP-NO-APP profile did not need surgery in 92% of its cases. These results were in good agreement with the US diagnosis of staff radiologists in the radiology department. A positive US raised the PTP-APP from 46.7% to 84%, while a negative US lowered the PTP-APP to 4%.[21,22]

According to a recent systematic review and meta-analysis if a compression ultrasound (CUS) was done first by non-radiologist clinicians in the emergency department (ED-POCUS [point of care ultrasound]) in pediatric patients with a pretest probability (prevalence) of 42.8% for appendicitis, a positive CUS scan would raise the PTP-APP to 87% and obviate the need for CT or magnetic resonance imaging (MRI). On the other hand, a negative CUS scan would lower the PTP-APP from 42.8% to 11% but could not rule out appendicitis with certainty so a CT scan or MRI was needed for diagnosis.[20] The "all positive" J-up risk profile of this study raised the probability for appendicitis from 46.7% to 85%, thus having a PTP-APP close to the model's test-treatment threshold PTP-APP of 87%, so it could obviate the need even for an ultrasound imaging and initiate therapy. The all negative J-up risk profile lowered the PTP-APP from 46.7% to 8%, and according to Benabbas' model, further imaging with CT scan or MRI is needed to lower the PTP-APP below the threshold of 0.2% to 0.3% that secures diagnosis of non-appendicitis and discharges patients home. We have estimated in our patients that if an "all negative" J-up risk profile is combined with a negative CUS, then the PTP-APP would be even lowered from 8% to 3%. This is closer to the 0.3% threshold and discharges patients home with a PTP of 97% of not having appendicitis would be a reasonable alternative, obviating the need for further imaging with CT or MRI.

Conclusion

The J-up test could be used as a clinical test to demonstrate peritonism in children complaining about acute RLQ abdominal pain. It is easy to perform by every doctor, even the most inexperienced and very acceptable by children. A positive or negative J-up test in combination with WBC count, neutrophils, NE/LY ratio, and CRP levels in peripheral blood could stratify RLQ abdominal pain patients into groups by a low, intermediate, or a high J-up risk profile for appendicitis. Patients with the lowest J-up risk profile have a 92% probability of not having appendicitis and would need observation and a no urgent diagnostic imaging in case of a deteriorating risk profile. Patients with an intermediate J-up risk profile would need diagnostic imaging to secure the diagnosis of the disorder. Patients with the highest J-up risk profile have an 85% probability of appendicitis and could be spared imaging given an urgent consultation with the surgical team (Figure 2). The highest and lowest risk J-up profiles predict which patient is in urgent need or not of surgery as they had a substantial agreement with the "gold standard" ultrasound diagnosis and with staff pediatric surgeons' final decision to operate or not children with RLQ abdominal pain.

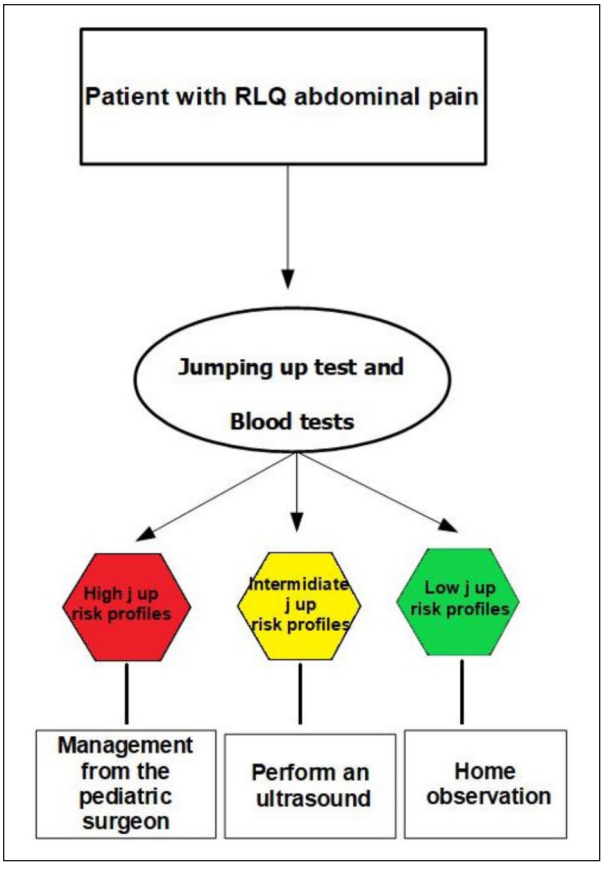

Figure 2. Management of children with right lower quadrant abdominal pain.

Author Contributions

AKT: Substantially contributed to conception or design; contributed to acquisition, analysis, or interpretation of data; drafted the manuscript; gave final approval; agrees to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

PG: Contributed to acquisition, analysis, or interpretation of data; drafted the manuscript; gave final approval; agrees to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

MT: Substantially contributed to conception or design; critically revised the manuscript for important intellectual content; gave final approval; agrees to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
NS: Substantially contributed to conception or design; critically revised the manuscript for important intellectual content; gave final approval; agrees to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
MV: Contributed to acquisition, analysis, or interpretation of data; gave final approval; agrees to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
AP: Critically revised the manuscript for important intellectual content; gave final approval; agrees to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
NZ: Substantially contributed to conception or design; critically revised the manuscript for important intellectual content; gave final approval; agrees to be accountable for all aspects of the work in ensuring that questions relating to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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