Original Study

Creation of a Composite Score to Predict Adnexal Torsion in Children and Adolescents

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A B S T R A C T

Study Objective: To create a composite score to predict adnexal torsion in children and adolescents.
Design: A prospective cross-sectional study.
Setting: Emergency department of a tertiary care children's hospital.
Participants: Three hundred twenty-four female participants aged 6-21 years who presented to the emergency department with lower abdominal pain and underwent ultrasound or computed tomography imaging.
Interventions: Collection of possible clinical and radiologic predictors of torsion.
Main Outcome Measures: The primary outcome was a composite score to predict adnexal torsion. We used χ^2 analyses to identify possible risk factors. The classification and regression tree decision method was used to identify risk factor cutoff points. Independent risk factors were combined into a composite score. Receiver operating characteristic curve analyses were used to assessed score performance.
Results: Of 324 participants with abdominal pain, 241 underwent imaging, and 6.6% (16 of 241) had torsion. Duration of pain, intermittent pain, nausea, and absence of arterial or venous flow were not associated with torsion. Vomiting ($P = .05$ in premenarchal subjects; $P < .001$ in menarchal subjects), adnexal volume ($P = .008$ in premenarchal subjects; $P < .001$ in menarchal subjects), and adnexal volume ratio ($P = .04$ in premenarchal subjects; $P < .001$ in menarchal subjects) were independent predictors of torsion. These predictors were incorporated into a composite score. No torsions were identified with a score of less than 2. There was an increasing risk of torsion for each 1-point score increase.
Conclusion: Independent predictors of torsion can reliably be combined into a composite score to identify children and adolescents at risk for adnexal torsion. This score might aid in improving triage and management of these challenging patients.
Key Words: Torsion, Ovary, Adnexa, Children, Adolescents, Female, Diagnosis, Composite score

Introduction

Lower abdominal pain is a common complaint in young women who present to the emergency department (ED). Although many of these patients have benign conditions, extensive evaluation might be required to exclude surgical emergencies, such as appendicitis or ovarian or adnexal torsion. Torsion is a rare event among girls and adolescents that can have potentially devastating long-term consequences, such as loss of the ovary or fallopian tube with decreased hormonal function or fertility, if not evaluated and treated promptly.[1]

The presentation of adnexal torsion is variable, and there are no definitive clinical or radiological tests.[1,2] Surgical exploration is the only definitive means of diagnosis. Many possible risk factors have been reported, including duration, acute onset, and intermittent nature of pain, nausea, vomiting, elevated serum interleukin 6, adnexal size, adnexal ratio, and absent Doppler flow, but many of these data were obtained retrospectively, and results have been inconsistent.[3–9] Previous retrospective work at our institution identified clinical and radiologic predictors of torsion and derived a composite score to help make this diagnosis in menarchal patients. Predictors included duration of symptoms, nausea and vomiting, adnexal volume, and affected to unaffected adnexal volume ratio.[10] However, data among premenarchal patients are limited.

Diagnostic algorithms and composite scores have been successfully implemented to streamline evaluation and management of other pediatric conditions.[11,12] Improved criteria for torsion could better triage appropriate patients to surgery and avoid unnecessary intervention for others. The objective of this study was to create a composite score among premenarchal as well as menarchal women to better predict adnexal torsion.

Materials and Methods

Study Setting and Population

This study took place in the pediatric ED of a tertiary care children's hospital from August 2007 to August 2009. Patients who were female, ages 6-21 years, had a chief

The authors indicate no conflicts of interest.

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complaint of lower abdominal pain, and underwent imaging with either ultrasound (US) or computed tomography (CT) that visualized the pelvis and reproductive structures were eligible to be included. Those who presented with current pregnancy, recent miscarriage or abortion, alleged abuse or trauma, or significant intellectual or developmental disabilities were excluded.

Study Design and Protocol

A multidisciplinary team of clinicians from Surgery, Gynecology, Emergency Medicine, and Radiology created a clinical pathway with a standardized data collection form for female patients who presented to the pediatric ED with lower abdominal pain. All patients who presented with abdominal pain were recruited for participation during hours when study personnel were available. This was typically 12-16 hours per day on weekdays and 8-12 hours per day on weekends. During these study hours, every eligible patient was identified through a computerized tracking system and approached by dedicated clinical research coordinators to offer and complete the enrollment process. Patient demographic characteristics were collected from the medical record. Data on presence of clinical symptoms were collected by the research coordinator via a face-to-face interview with each patient and family and recorded on a standardized data collection form. Physical exam findings by the examining clinician were recorded on the data collection form. Laboratory studies and radiologic findings were abstracted from the medical record. The choice of imaging modalities was made by the evaluating clinician and was on the basis of presenting symptoms and clinical judgement. In our institution, US is the initial imaging study for abdominal pain, but because some of the patients were initially seen and evaluated at outside hospitals, a CT scan might have been obtained first, especially in cases in which appendicitis was suspected. Doppler flow was investigated on US imaging at the discretion of the ordering and performing clinicians. Our hospital's US protocol typically includes evaluation of Doppler flow, but this was not always performed at outside institutions. Final diagnoses and dispositions, including surgical procedures, intraoperative findings, and pathology reports, were obtained via review of the medical record.

Outcome Measures

Data were deidentified and entered into protected databases. Potential predictor variables of torsion were chosen on the basis of those identified in previous studies and included acute onset of pain, duration of pain, chronic vs intermittent nature of pain, nausea, vomiting, adnexal volume, adnexal ratio, and arterial as well as venous Doppler flow.[3–10] Adnexal volume was defined as the total volume of the affected adnexa, because it can be difficult to distinguish the origin of a cystic lesion between the ovary, fallopian tube, and broad ligament on the basis of imaging, and all such lesions can predispose to torsion. Adnexal ratio was defined as the ratio of the volume of the affected side compared with the unaffected side, as identified using imaging, because not all patients underwent surgical exploration.

Statistical Analyses

Analyses were initially performed on the entire population and were then stratified among premenarchal and menarchal patients because of significant expected differences in measures such as adnexal volume. We used χ^2 analyses and Fisher exact tests to identify risk factors associated with adnexal torsion, and an odds ratio with confidence intervals was calculated for each risk factor. Two-sided P values of .05 or less were considered statistically significant. Variables that were found to be independent risk factors for adnexal torsion were further analyzed using classification and regression tree (CART) decision method analysis to determine appropriate cutoff points for risk factors involving continuous data, including volumes and ratios. These independent risk factors were then combined into a composite score, giving equal weight (0-2 points) to each of the independent variables. Separate but analogous composite scores were created for premenarchal and menarchal patients. These indices contained the same variables but with different cutoff points determined using the CART decision method analysis in each group.

The performance of the composite score to predict adnexal torsion was evaluated using receiver operating characteristic (ROC) curve analyses using a logistic model. ROC analysis is used to measure the accuracy of predictive models using measures of sensitivity and specificity.

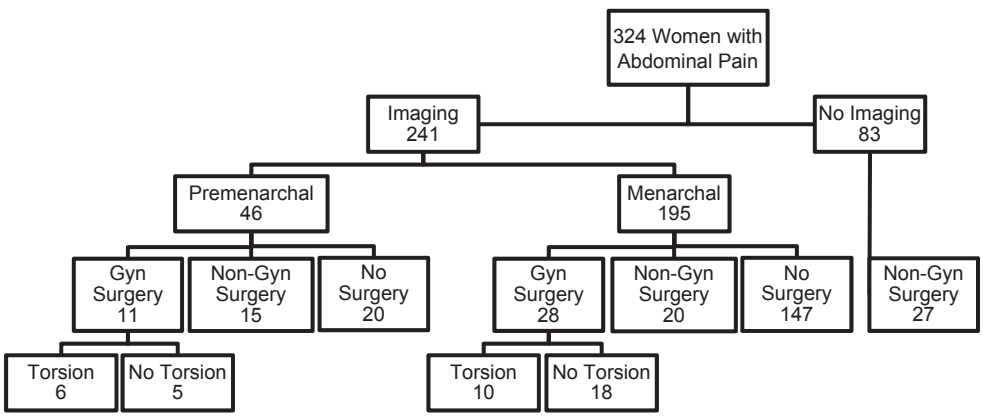

Fig. 1. Flow chart of study subjects. Gyn, gynecologic.

The area under the curve is often used as a summary statistic, with an area of 1 representing a perfect test and an area of 0.5 mere chance.

CART analyses were performed using SAS JMP 12 (SAS Institute Inc). All other analyses were performed using SAS STAT 9.4 package (SAS Institute Inc). This study was reviewed and approved by the Cincinnati Children's Hospital Medical Center institutional review board.

Results

There were 324 female patients who presented to the pediatric ED with a complaint of abdominal pain and were enrolled during the study time period, and 241 underwent imaging with either US or CT. Of those who underwent imaging, 196 had an US examination and 108 had a CT scan. There was some overlap in imaging modalities, with 63 subjects undergoing both imaging studies. Doppler flow was investigated in 165 (84.2%) US examinations. Thirty-nine patients (16.2% of the 241 patients whose abdominal pain warranted imaging) underwent surgical exploration by Gynecology, and 16 (6.6% of the 241 patients with imaging and 41% of the 39 patients who had gynecologic surgery) were found to have adnexal torsion (Fig. 1).

Among the 16 subjects with torsion, 14 underwent US imaging and 7 had a CT scan, with 5 patients having both studies. All US examinations were performed with Doppler. All cases of torsion were unilateral. Four subjects had ovarian torsion, 3 had tubal torsion, and 9 had torsion of the entire adnexa. An underlying cyst or mass was present in the ovary in 6 patients, in the paratubal region or broad ligament in 4, and of unclear origin in 1. No underlying mass was noted in 5 subjects. Of the 23 subjects who underwent surgical exploration by Gynecology and were not found to have torsion, 16 had an ovarian or paratubal cyst, 1 had a tubo-ovarian abscess, 2 had appendicitis, and 3 had no identifiable pathology. An additional 62 patients were taken to the operating room by Surgery because of clinical concern for appendicitis, with 61 confirmed to have appendicitis. Of these patients, 27 did not have any imaging before undergoing surgery and were thus not included in this study. To our knowledge, none of the patients who did not undergo surgical exploration returned to the ED and required short-interval surgical intervention.

Mean (±SD) premenarchal subject age was 9.9 (±2.1) years, with mean menarchal subject age 15.4 (±2.1) years. Most subjects (83%, 200 of 241) were white. Adnexal torsion was not associated with duration of pain, intermittent nature of pain, presence of nausea alone, or absence of either arterial or venous flow in either premenarchal or menarchal subjects. The presence of vomiting ($P = .05$ in premenarchal subjects, $P < .001$ in menarchal patients), adnexal volume ($P = .008$ in premenarchal subjects, $P < .001$ in menarchal subjects), and affected to unaffected adnexal volume ratio ($P = .04$ in premenarchal subjects, $P < .001$ in menarchal subjects) were found to be independent predictors of torsion in premenarchal as well as menarchal subjects. These 2 groups were analyzed separately because widely different cutoff points were found for adnexal volume as well as adnexal volume ratio, as shown in Tables 1 and 2. CART decision tree analysis was used to determine 2 cutoff points (6 mL and 17 mL) for adnexal volume in premenarchal subjects. Among menarchal subjects, only a single cutoff point of 105 mL was found with similar analysis. There were also 2 cutoff points statistically determined for adnexal ratio for premenarchal as well as menarchal subjects (1.25 and 21 in premenarchal subjects and 2 and 21 in menarchal subjects). The independent predictors of vomiting, adnexal

Table 1
Risk Factors for Adnexal Torsion in Premenarchal Subjects

Risk Factor	Torsion (n = 6)	No Torsion (n = 40)	Odds Ratio (95% CI)	*P*
Duration of pain				
24 Hours or less	2 (33)	18 (45)	0.58 (0.10-3.57)	.68
48 Hours or less	3 (50)	29 (73)	0.34 (0.06-1.99)	.33
Intermittent nature of pain				
Yes	3 (50)	19 (48)	1.11 (0.20-6.15)	.91
Presence of nausea				
Yes	4 (67)	25 (63)	1.12 (0.18-6.91)	.90
Presence of vomiting				
Yes	5 (83)	16 (40)	7.19 (0.77-67.5)	.05
Adnexal volume, mL*				
Less than 6	0 (0)	11 (28)	Reference	.008
6-17	2 (33)	7 (18)	7.67 (0.32-183)	
More than 17	4 (67)	2 (5)	41.1 (1.64-1042)	
Adnexal ratio (affected to unaffected)				
Less than 1.25	0 (0)	9 (23)	Reference	.04
1.25-21	5 (83)	11 (28)	9.09 (0.44-186)	
More than 21	1 (17)	0 (0)	57 (0.78-4123)	
Arterial flow (affected adnexa)†				
Present	5 (83)	40 (100)	22.1 (0.80-612)	.13
Absent	1 (17)	0 (0)	NA	
Venous flow (affected adnexa)				
Present	5 (83)	40 (100)	22.1 (0.80-612)	.13
Absent	1 (17)	0 (0)	NA	

CI, confidence interval; NA, not applicable
Data are presented as n (%) except where otherwise noted.
* Adnexal volume and ratio cutoff points determined using classification and regression tree decision method analysis.
† Missing data on Doppler flow was included as if it were present.

Table 2
Risk Factors for Adnexal Torsion in Menarchal Subjects

Risk Factor	Torsion (n = 10)	No Torsion (n = 185)	Odds Ratio (95% CI)	*P*
Duration of pain				
24 Hours or less	3 (30)	70 (38)	0.70 (0.18-2.81)	.62
48 Hours or less	5 (50)	114 (62)	0.62 (0.17-2.23)	.52
Intermittent nature of pain				
Yes	3 (30)	93 (50)	0.42 (0.11-1.69)	.33
Presence of nausea				
Yes	7 (70)	115 (62)	1.42 (0.36-5.67)	.75
Presence of vomiting				
Yes	10 (100)	63 (34)	40.2 (2.32-697)	<.001
Adnexal volume, mL*				
Less than 105	3 (30)	180 (97)	Reference	<.001
105 or more	7 (70)	5 (3)	84.0 (16.7-424)	
Adnexal ratio (affected to unaffected)				
Less than 2	0 (0)	83 (45)	Reference	<.001
2-21	3 (30)	69 (37)	8.41 (0.43-166)	
21 or more	5 (50)	4 (2)	204 (9.70-4295)	
Arterial flow (affected adnexa)†				
Absent	0 (0)	7 (4)	3.31 (0.36-30.5)	.31
Venous flow (affected adnexa)				
Absent	0 (0)	10 (5)	1.94 (0.22-16.9)	.45

CI, confidence interval
Data are presented as n (%) except where otherwise noted.
* Adnexal volume and ratio cutoff points determined using classification and regression tree decision method analysis.
† Missing data on Doppler flow was included as if it were present.

Table 3
Generation of Composite Scores

Independent Risk Factor	Value		Score
	Premenarchal	Menarchal	
Vomiting	No	No	0
	Yes	Yes	2
Adnexal volume, mL	Less than 6	Less than 105	0
	6-17		1
	More than 17	105 or more	2
Adnexal ratio	Less than 1.25	Less than 2	0
	1.25-21	2-21	1
	More than 21	More than 21	2
Composite score			Total (0-6)

volume, and adnexal ratio were then incorporated into a composite score with a range of 0-6 (Table 3). There were 2 separate but analogous scores for premenarchal and menarchal patients because of differences in volume and ratio cutoff points.

There was an increasing risk of torsion for each 1-point increase in the composite score (Table 4). No cases of torsion were identified in any subjects who had a composite score of 0 or 1. Among the 34 subjects with a score of 2, only 1 case of torsion was found in a premenarchal 6-year-old girl. Among the 21 subjects who went to the operating room and were not found to have torsion, 10 (48%) had a composite score of 0 or 1, with an additional 4 (19%) with a composite score of 2, and 5 (24%) with a score of 3. One each had scores of 5 and 6 (Table 5).

ROC curve analysis was used to evaluate the accuracy of the composite score model. The area under the curve was found to be 0.9488 (Fig. 2).

Discussion

To our knowledge, this study is the first to use prospective data and include premenarchal subjects to derive a composite score to help predict adnexal torsion. Previous studies have been small, retrospective, and had conflicting results.[3–9] There are minimal data on premenarchal patients, and only 1 study has separately analyzed risk factors for premenarchal and menarchal patients.[13]

We found that vomiting, adnexal volume, and adnexal volume ratio were independent predictors of torsion in premenarchal as well as menarchal patients. This discrepancy of vomiting as a risk factor in previous studies might be because many do not distinguish between nausea and vomiting.[1,3,4,9] We found that although nausea was widespread, vomiting was significantly more prevalent in the torsion group. In addition, torsion was seen in only a single subject who denied vomiting, potentially identifying a lack

Table 4
Risk of Adnexal Torsion According to Composite Score

Composite Score	0 (n = 60)	1 (n = 49)	2 (n = 34)	3 (n = 29)	4 (n = 4)	5 (n = 6)	6 (n = 7)
Torsion (n = 14)	0 (0)	0 (0)	1 (3)	3 (10)	1 (25)	3 (50)	6 (86)
No torsion (n = 175)	60 (100)	49 (100)	33 (97)	26 (90)	3 (75)	3 (50)	1 (14)

Data are presented as n (%).

Table 5
Risk of Adnexal Torsion According to Composite Score in Subjects Who Were Taken to the OR

Composite Score	0 (n = 3)	1 (n = 7)	2 (n = 5)	3 (n = 8)	4 (n = 1)	5 (n = 4)	6 (n = 7)
Torsion (n = 14)	0 (0)	0 (0)	1 (20)	3 (38)	1 (100)	3 (75)	6 (86)
No torsion (n = 21)	3 (100)	7 (100)	4 (80)	5 (62)	0 (0)	1 (25)	1 (14)

OR, operating room
Data are presented as n (%).

of vomiting as a very useful negative predictive factor. Our data also confirmed previous findings of the importance of an enlarged adnexa.[1,2,6,9] However, only 1 previous study in menarchal adolescents has suggested an absolute volume threshold (>75 mL) as being predictive of torsion. This study also noted that there were no cases of torsion with a volume of less than 20 mL.[5] No studies have reported volume thresholds for premenarchal girls. Our study used statistical methodology to identify volume and ratio thresholds in both subgroups.

We also found that several previously reported markers of torsion were not accurate predictors in our study. Duration of pain, intermittent nature of pain, nausea alone, and absence of arterial or venous Doppler flow on US images were not associated with torsion. Although absence of Doppler flow was once a hallmark of the diagnosis and was reported to be 100% sensitive and 98% specific for the diagnosis,[14] numerous studies have shown that the absence of flow does not conclusively prove the diagnosis and the presence of flow does not eliminate the possibility.[1,2,5,6] Despite this, Doppler studies are routinely obtained as part of the evaluation of women with lower abdominal pain. This study provides further evidence that Doppler flow does not aid in this evaluation. Clinicians should not rely upon Doppler studies when evaluating patients for possible adnexal torsion, and should consider not ordering it. The elimination of routine Doppler testing could lead to increased efficiency of diagnosis and reduced health care costs.

We also showed that independent predictors of torsion can be accurately combined into a composite score to identify patients at higher risk for adnexal torsion. Statistical analysis of this model using ROC analysis showed high sensitivity and specificity of the score. A previously generated composite score at our institution showed promise but was developed retrospectively and included only menarchal patients.[10] This was never applied or studied prospectively. Use of a score to streamline evaluation and management of patients with possible torsion might help preserve adnexal function and fertility.

Although the current scoring system has not yet been put into an official protocol or clinical guideline in our institution, we have incorporated it into our clinical practice as follows: with a score of 0-1, we would predict a low risk of torsion and defer surgery. At a score of 4 or higher, we would recommend surgical exploration, because more than 25% of patients had torsion. With a score of 2-3, 3%-10% of subjects had torsion, so we would carefully weigh the risks of surgery vs expectant management. Analysis of our

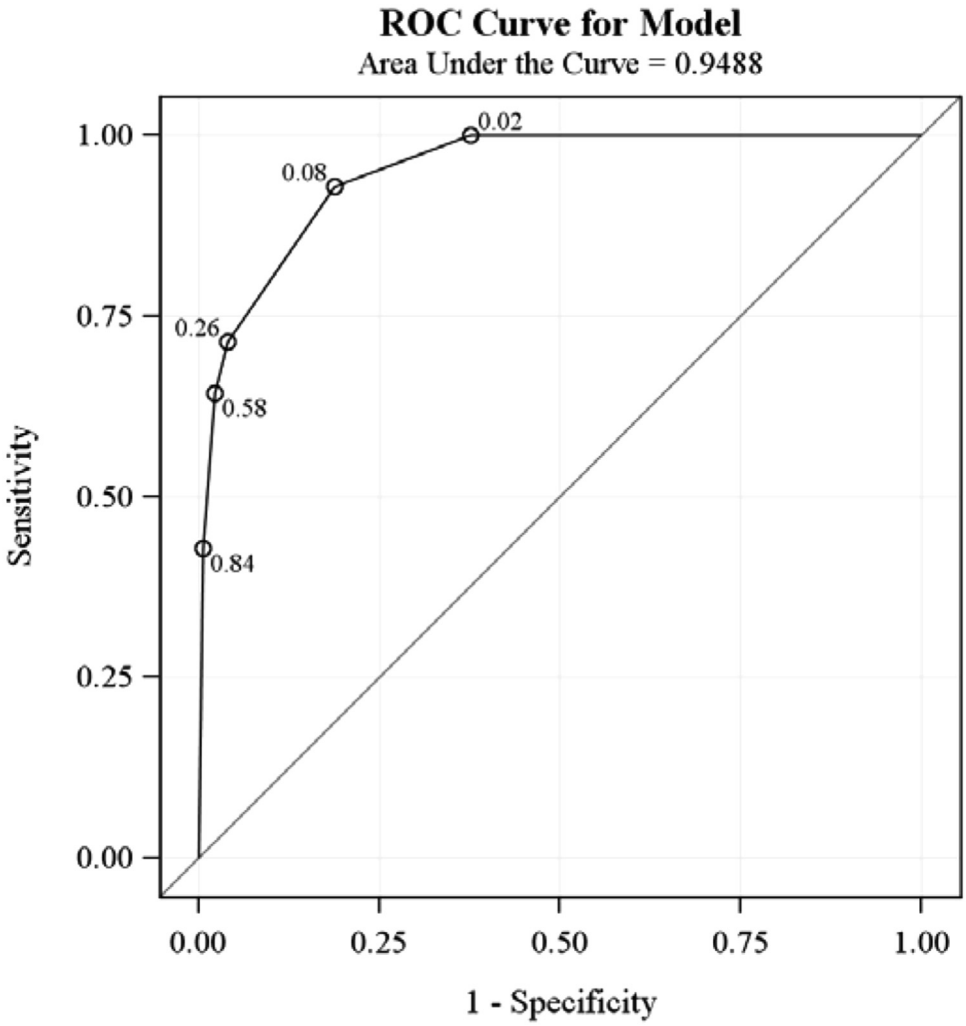

Fig. 2. Receiver operating characteristic (ROC) curve analysis for the composite score model as a predictor of adnexal torsion.

subjects who went to the operating room and were not found to have torsion showed that, using our score, 10 surgeries (48%) might have been prevented because of a composite score of 0-1, with another 9 subjects (43%) with a score of 2-3.

Limitations of the study include the small number of subjects with surgically diagnosed torsion. In addition, 2 subjects with torsion were excluded from composite score analysis because of missing data. In both of these cases, outside hospital CT imaging precluded the ability to obtain accurate 3-dimensional measurements to calculate adnexal volumes. In our institution, US is the initial imaging modality, but this is not always true, especially in adult hospitals. Cases of torsion might also have been missed in subjects not taken to the operating room, but this limitation is common to all studies that require surgery for definitive diagnosis.

The indication for imaging, including the clinical degree of suspicion for torsion, was not always clear. The differential diagnosis of lower abdominal pain typically includes constipation, urinary tract infection, viral etiology, appendicitis, ovarian cyst, and ovarian torsion. When imaging is ordered, the ovaries as well as the appendix are usually studied nearly simultaneously; thus it is difficult to limit this study to those in whom torsion alone was suspected. There was a subset of patients who were excluded from the denominator of the study because of such a high degree of clinical suspicion for appendicitis that the decision was made to proceed to surgery without obtaining imaging. However, in most patients, appendicitis as well as torsion were part of the differential diagnosis and imaging was obtained to investigate both possible etiologies of pain.

Last, although the study population was large in number, and data were collected prospectively, it was obtained via a convenience sample only during the hours when research coordinators were available. Although all eligible patients were included during these study hours, unknown factors might have biased the sample by not including patients who presented to the ED when study personnel were not present.

This study showed that independent predictors of torsion can reliably be combined into a composite score to better identify patients at risk for torsion. This score might improve triage, evaluation, and management of young women who present to the ED with lower abdominal pain. Although torsion often can be conservatively successfully

managed with adnexal sparing,[15–18] surgical management sometimes results in salpingo-oophorectomy.[19,20] Increased accuracy and efficiency of the diagnosis could lead to fewer unnecessary surgical interventions and especially oophorectomy. Future studies are needed to prospectively test and validate this score, especially because of the relatively small sample size used to create the composite score. Because of the relative rarity of this condition, a multicenter study would allow for a larger population and increased generalizability of this predictive model.

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