in vivo *37*: 2597-2608 (2023)
doi:10.21873/invivo.13367

Accuracy of Prediction Models in Diagnosis of Acute Diverticulitis

MAARET ESKELINEN[1,2], JUKKA PULKKINEN[1], TUOMAS SELANDER[3], KARI SYRJÄNEN[4,5] and MATTI ESKELINEN[1,2]

[1]*Department of Surgery, Kuopio University Hospital (KUH), Kuopio, Finland;*
[2]*School of Medicine, University of Eastern Finland (UEF), Kuopio, Finland;*
[3]*Science Service Center, KUH, Kuopio, Finland;*
[4]*Molecular Oncology Research Center, Barretos Cancer Hospital, Barretos, Brazil;*
[5]*SMW Consultants, Ltd., Kaarina, Finland*

Abstract. *Background/Aim: The diagnostic score models (DMs) for patients with acute diverticulitis (AcDi) have been rarely evaluated. Therefore, we tried to develop diagnostic models (DMs) to enhance the diagnostic accuracy (DA) of AcDi. Patients and Methods: In this AAP (acute abdominal pain) cohort, 30 AcDi patients were compared to 1,303 non-AcDi patients, with regard to their i) clinical symptoms (n=22), ii) signs and tests (n=14) as well as iii) laboratory analyses (n=3). The triage was performed at patient arrival to the emergency department (ED) (triage I) and at follow-up (triage II) before final decision. The triage included a suggested diagnosis of the AAP patient. Bivariate random effects meta-analysis was performed separately for 1) the pooled symptoms (n=22), 2) signs & tests (n=17) as well as 3) pooled DMs (I-V) with different cut-offs (with or without triage) to assess the diagnostic accuracy (DA) in detection of AcDi by HSROC (hierarchical summary receiver operating characteristic) curves. Results: In the conventional receiver operating characteristic (ROC) analysis (for test optimization and finding optimal cut-off points), the area under curve (AUC) reached the following values for AcDi: i) DM without triage, AUC=0.843, ii) DM with triage I, AUC=0.866 and iii) DM with triage I and II, AUC=0.926. In the HSROC analysis, the AUC values for detection of AcDi were as follows; i) pooled clinical symptoms, AUC=0.540, ii) pooled clinical signs & tests, AUC=0.556 and iii) pooled DMs globally, AUC=0.853. In roccomp analysis for differences in AUC values: i) and iii) p<0.0001; between ii) and iii) p<0.0001. Conclusion: As confirmed by ROC and HSROC analysis, the new DMs with triage mode proved to be far superior in their DA for AcDi as compared to both symptoms and signs & tests. In the lack of earlier studies, these data report the first evidence that the DM including triage at an ED could improve the detection of AcDi.*

Of all AAP (acute abdominal pain) patients referred to the emergency department (ED), acute diverticulitis (AcDi) is one of the most common diagnoses and among the main gastroenterological causes of hospitalization in the Western world (1-9), thus requiring more attention. AcDi is portrayed by an acute inflammation of the colonic diverticulum leading to focal necrosis of the diverticular wall, with a potential to result in a microscopic or macroscopic perforation of a diverticulum. In addition, the diverticulum itself and the adjacent inflamed colon could obstruct, leading to the full-blown clinical picture of a large bowel obstruction.

Because of these divergent clinical presentations, descriptions of the clinical appearances of AcDi in the literature are somewhat fragmentary and even contradictory. Although lower abdominal (Lab) pain, increased body temperature (Tax), abdominal guarding and absence of vomiting are suggested to predict AcDi in some reports (3-5), international guidelines for diagnosis and treatment of AcDi do not advocate basing the diagnosis of AcDi on only the clinical symptoms, signs, and laboratory tests of the patient (1-9). Therefore, some authors have tried to develop diagnostic models (DMs) to enhance the diagnostic accuracy (DA) of AcDi, but these DMs have not yet been validated and the most studies are based on a small sample size (10-15). In addition, some of the introduced DM scores, *e.g.*,

Correspondence to: Matti Eskelinen, MD, Ph.D., School of Medicine, University of Eastern Finland, P.O. Box 100, FI-70029 KYS, Kuopio, Finland. Tel: +358 17173311, Fax: +358 17172611, GSM: +358 400969444, e-mail: matti.eskelinen@kuh.fi

Key Words: Acute diverticulitis, symptoms, signs, tests, diagnostic score, HSROC, diagnostic accuracy.

Table I. *The clinical history of the acute diverticulitis (AcDi) versus other causes of acute abdominal pain.*

Clinical history variable	Positive endpoint	Negative endpoint	TP	FN	FP	TN
1. Location of initial pain	Left lower and lower abdomen	Other	12	18	222	682
2. Location of pain at diagnosis	Upper abdomen	Other	12	18	201	1,102
3. Duration of pain	≤24 hours	>24 hours	15	15	768	535
4. Intensity of pain	Subjectively moderate or intolerable pain	Weak pain	22	8	851	452
5. Progression of pain from onset to diagnosis	Subjectively same or worse pain	Weaker pain than at the onset	18	12	870	433
6. Type of pain	Subjectively steady or intermittent pain	Colicky pain	20	10	895	408
7. Aggravating factors	Movement, coughing, respiration or food	No aggravating factors	6	24	350	953
8. Relieving factors	Rest, vomiting or none	Food, antacid or other	28	2	1,183	120
9. Previous similar pain	Yes	No	6	24	441	848
10. Vertigo	No	Yes	30	0	1,259	40
11. Nausea	Yes	No	13	17	753	550
12. Vomiting	Yes	No	8	22	567	736
13. Appetite	Poor appetite	Normal appetite	22	8	955	348
14. Previous indigestion	Yes	No	5	25	274	1,027
15. Jaundice	No	Yes	30	0	1,270	33
16. Bowels	Diarrhea, constipation	Blood, mucus, white stools or normal	4	26	291	1,012
17. Micturition	Normal	Abnormal	29	1	1,298	85
18. Drugs for abdominal pain	No	Yes	28	1	1,250	53
19. Previous abdominal surgery	No	Yes	22	7	977	326
20. Previous abdominal diseases	Yes	No	4	25	230	1,073
21. Use of alcohol	No	Yes	28	1	1,237	66
22. Sex	Male	Female	15	15	682	621

FN: False-negative; FP: false-positive; TN: true negative; TP; true positive.

those of Andeweg *et al*. (12) and Bolkenstein *et al*. (14) include C-reactive protein (CRP) level (12) or leucocyte count (Leuc) (14). Although their proposed DMs could slightly enhance the DA in ruling out non-AcDi diagnoses, the laboratory tests included in these DMs are a disadvantage, because many of these are not available at the ED settings, thus precluding an accurate prediction of the disease progression by the emergency physicians.

The present study is the first where the DA of the i) symptoms, ii) signs & tests, as well three DM score models (without triage, with one triage and with two triages) were compared among AcDi and non-AcDi patients, included in a cohort of 1,333 AAP patients (16, 17).

Patients and Methods

The AcDi study group comprised of 30 patients with AcDi and 1,303 patients in the non- AcDi group. The clinical symptoms (*n*=22), signs and tests (*n*=14) as well as laboratory analyses (*n*=3) were recorded for each patient. The diagnosis of AcDi was confirmed by considering all clinical history-taking details, clinical findings, and results of the laboratory tests together and following the diagnostic criteria of AAP (acute abdominal pain) and AcDi. The triage was performed at arrival to ED unit (triage I) and at follow-up (triage II) before final decision. The triage included a suggestion of possible diagnosis for AAP patient.

DM models. In a multivariate logistic (stepwise) regression analysis SPSS software was used (SPSS statistics 26.0.0.1; IBM, Armonk, NY, USA) and the clinical features shown in Table I and Table II were included in the stepwise analysis as binary data *e.g.,* AcDi=1 and other diagnosis of AAP=0. Using the coefficients of the stepwise model, a DM was built and its predictive value for AcDi was estimated.

1. The DM for AcDi without triage (PE=positive endpoint and NE=negative endpoint):

DM=–0.75×Progression of pain (PE=1, NE=0)-0.92×Vomiting (PE=1, NE=0)+2.35×Tenderness (PE=1, NE=0)+2.37×Rigidity (PE=1, NE=0)-1.18×Leuc (PE=1, NE=0)-4.79.

2. The DM for AcDi with triage at ED (Triage I):

DM=–1.10×Progression of pain (PE=1, NE=0)-0.79×Previous similar pain (PE=1, NE=0)+1.57×Tenderness (PE=1, NE=0)+1.22×Guarding (PE=1, NE=0)+1.49×Rigidity (PE=1, NE=0)-1.51×Leuc (PE=1, NE=0)+4.44×Triage I (PE=1, NE=0)-4.34.

3. *The DM for AcDi with triage at ED (triage I) and at follow-up (triage II):*

DM=–1.11×Progression of pain (PE=1, NE=0)-0.73×Vomiting (PE=1, NE=0)-1.09×Bowels (PE=1, NE=0)+1.66×Tenderness (PE=1, NE=0)+0.96×Guarding (PE=1, NE=0)+1.57×Rigidity (PE=1, NE=0)-0.65×Body temperature (PE=1, NE=0)-1.41×Leuc (PE=1, NE=0)+3.72×Urine (PE=1, NE=0)+4.07×Triage I (PE=1, NE=0)+1.16×Triage II (PE=1, NE=0)-8.26.

Table II. *The clinical signs and investigations of the acute diverticulitis (AcDi) patients versus other causes of acute abdominal pain.*

Clinical signs and investigations	Positive endpoint	Negative endpoint	TP	FN	FP	TN
1. Mood	Distressed or anxious	Normal	6	24	221	1,082
2. Color	Normal	Jaundiced, pale, flushed or cyanosed	27	3	1,154	149
3. Abdominal movement	Poor/nil	Normal	2	28	91	1,211
4. Scar	No	Yes	23	7	963	339
5. Distension	Yes	No	3	27	90	1,209
6. Tenderness	Left lower and lower abdomen	Other	15	15	181	1,113
7. Mass	Yes	No	2	28	32	1,271
8. Rebound	Yes	No	18	12	613	690
9. Guarding	Yes	No	22	8	685	618
10. Rigidity	Yes	No	15	15	279	1,023
11. Murphy's positive	Yes	No	1	29	123	1,179
12. Bowel sounds	Abnormal	Normal	7	23	182	1,121
13. Renal tenderness	Left or both sides.	No	3	27	118	1,165
14. Rectal digital tenderness	Normal	Abnormal	19	11	950	350
15. Body temperature	≥37.5˚C	<37.5˚C	13	16	673	550
16. Leucocyte count (LC)	≥9 200/mm^3	<9 200/mm^3	8	19	541	513
17. Urine	Normal	Abnormal	25	0	1,071	72

FN: False-negative; FP: false-positive; TN: true negative; TP; true positive.

Table III. *Diagnostic score models (DM) for acute diverticulitis (AcDi) patients. The DM shown at six different cut-off levels of symptoms, signs, and tests. DM I and II; only symptoms and signs without triage at emergency department (ED). Cut-off levels: DM I=–4.00, DM II=–3.41, DM III and IV; symptoms and signs with triage at ED (triage I). Cut-off levels: DM III=–4.00, DM IV=–3.17. DM V and DS VI; symptoms and signs with triage I and with triage at follow-up (triage II). DM V=–5.00, DM VI=–4.13.*

Diagnostic score (DS)	Positive endpoint	Negative endpoint	TP	FN	FP	TN
1. DM I, no triage.	Acute diverticulitis	Other cause of abdominal pain	23	7	349	954
2. DM II, no triage.	Acute diverticulitis	Other cause of abdominal pain	21	9	244	1,059
3. DM III, triage at ED.	Acute diverticulitis	Other cause of abdominal pain	23	7	292	1,011
4. DM IV, triage at ED.	Acute diverticulitis	Other cause of abdominal pain	21	9	156	1,147
5. DM V, triage at ED and at follow-up.	Acute diverticulitis	Other cause of abdominal pain	29	1	464	839
6. DM VI, triage at ED and at follow-up.	Acute diverticulitis	Other cause of abdominal pain	25	5	267	1,036

FN: False-negative; FP: false-positive; TN: true negative; TP; true positive.

Statistical analysis. STATA/SE version 17.1 (StataCorp, College Station, TX, USA) and SPSS statistics 26.0.0.1 (IBM, Armonk, NY, USA) was used for statistical analysis. The statistical tests presented were two-sided, and p-values <0.05 was considered statistically significant. Using 2×2 tables, sensitivity (Se) and specificity (Sp) with 95% confidence intervals (95% CI) for each clinical history-taking variables, findings or tests were determined. Meta-analytical technique (metaprop) was used to create separate forest plots for Se and Sp for each set of data, including each diagnostic variable. Roccomp test (STATA) was used to compare the AUC values of the SROCs between the 3 diagnostic sets (history-taking, clinical signs, DMs). Conventional ROC analysis was used to find the optimal cut-off values for each of the DMs.

Results

The history taking in AcDi. The overall Se of the clinical symptoms for AcDi was 61% (95% CI=45-76%) (Figure 1). The Se was higher than 61% for 10 of the symptoms. The six most sensitive clinical history-taking variables (relieving factors, vertigo, jaundice, micturition, drugs for abdominal pain, use of alcohol) showed 93-100% Se in diagnosis of AcDi (Figure 1). The overall Sp of the history-taking for detecting AcDi was only 39% (95% CI=25-53%) (Figure 2). Altogether, 11 symptoms showed Sp higher than 39%. The

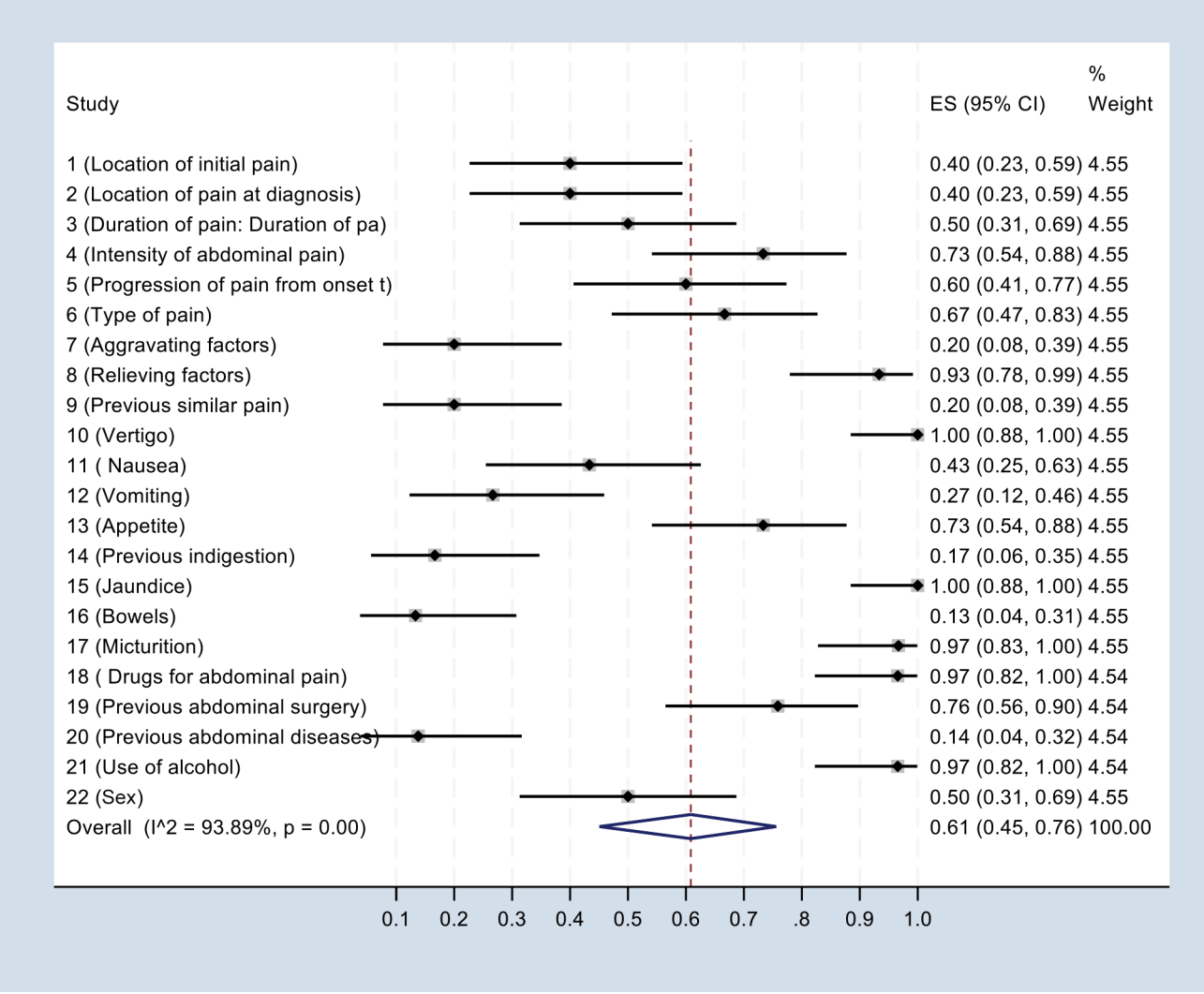

Figure 1. *Sensitivities of history-taking in acute diverticulitis (AcDi) (random-effects model). ES: Estimated sensitivity; CI: confidence interval.*

six most specific symptoms of AcDi (location of initial pain, location of pain at diagnosis, aggravating factors, previous similar pain, previous indigestion, bowels, previous abdominal diseases) showed 73-85% Sp (Figure 2).

Examination and tests in AcDi. The overall Se of the signs & tests for AcDi was 41% (95% CI=25-59%) (Figure 3), and 9 signs & tests had Se exceeding 41%. The six most accurate signs & tests (colour, scar, rebound, guarding, rectal digital tenderness, urine) showed 60-100% Se (Figure 3). The overall Sp of the signs & tests was 65% (95% CI=48-80%) (Figure 4), while 9 signs & tests showed Sp higher than 65%. The five most specific signs & tests (abdominal movement, distension, mass, Murphy's positive, renal tenderness) showed 91-98% Sp (Figure 4).

DM without triage in AcDi. The most prominent features of AcDi in stepwise analysis without triage mode were progression of pain, vomiting, tenderness, rigidity and Leuc. The best diagnostic level for DM score without triage [DM I; Se=77%, Sp=73%, efficiency (Eff)=73%] was reached at cut-off level –4.0 for DM (Figure 5 and Figure 6; Table III).

DM with triage I mode in AcDi. The most prominent features of AcDi in stepwise analysis with triage I mode were progression of pain, previous similar pain, tenderness, guarding, rigidity, Leuc and triage I (AcDi *versus* non-AcDi). The best diagnostic level for DM with triage I mode (DM IV; Se=70%, Sp=88%, Eff=88%) was reached at cut-off level –3.17 for DM (Figure 5 and Figure 6; Table III).

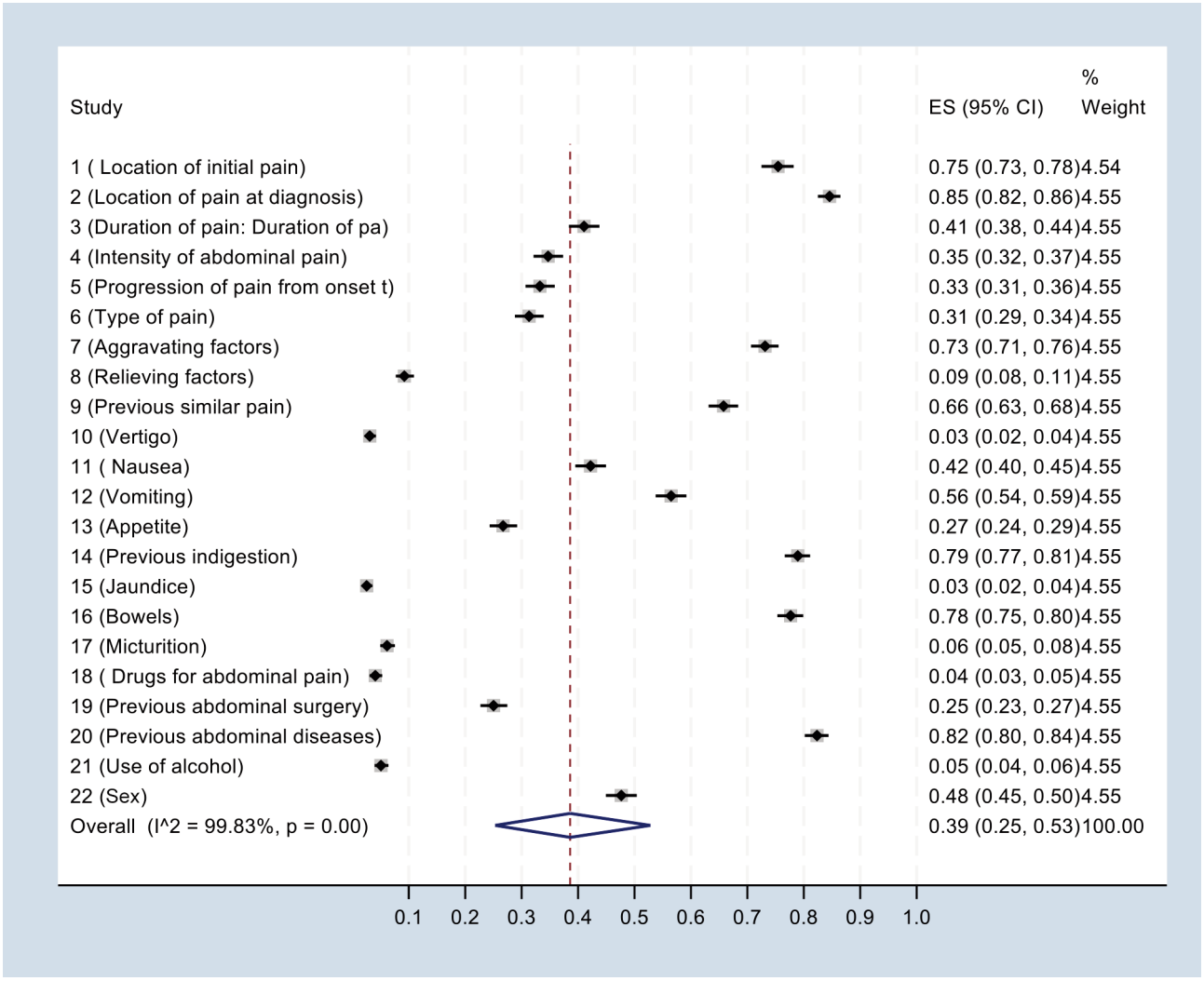

Figure 2. *Specificities of history-taking in acute diverticulitis (AcDi) (random-effects model). ES: Estimated specificity; CI: confidence interval.*

DM with two triage modes (triage I+triage II) in AcDi. The most prominent features of AcDi in stepwise analysis with triage I+II mode were progression of pain, vomiting, bowels, tenderness, guarding, rigidity, body temperature (Tax), Leuc, urine, triage I and triage II (AcDi *versus* non-AcDi). The best diagnostic level for DM with triage I+II mode (DM VI; Se=83%, Sp=80%, Eff=80%) was reached at cut-off level –4.13 for DM (Figure 5 and Figure 6). The overall Se and Sp of these six DM formulas was 80% (95% CI=70-88%) and 78% (95% CI=71-84%), respectively (Figure 5 and Figure 6). Two of these formulas showed Se ≥80% and four formulas had Sp ≥78%.

ROC, HSROC and AUC values. In the conventional ROC analysis for test optimization and finding optimal cut-off points, the AUC values for AcDi; i) DM without triage, AUC=0.843, ii) DM with triage I, AUC=0.866 and iii) DM with triage I and II, AUC=0.926. HSROC curves were used to visualise the pooled overall accuracy of the symptoms (Figure 7), signs & tests (Figure 8) and different DM models (Figure 9) in detecting AcDi. In SROC analysis, the AUC values for i) symptoms ii) signs & tests iii) DM were as follows: i) AUC=0.540 (95% CI=0.490-0.590); ii) AUC=0.556 (95% CI=0.496-0.616), and iii) AUC=0.853 (95% CI=0.813-0.893). The differences between these AUC values (roccomp analysis) are as follows: between i) and ii) p=0.664; between i) and iii) p<0.0001; between ii) and iii) p<0.0001.

Discussion

Prompted by the difficulty of AcDi diagnosis among the AAP patients, some authors have attempted to develop DMs in order to enhance the DA, but these DMs remain still

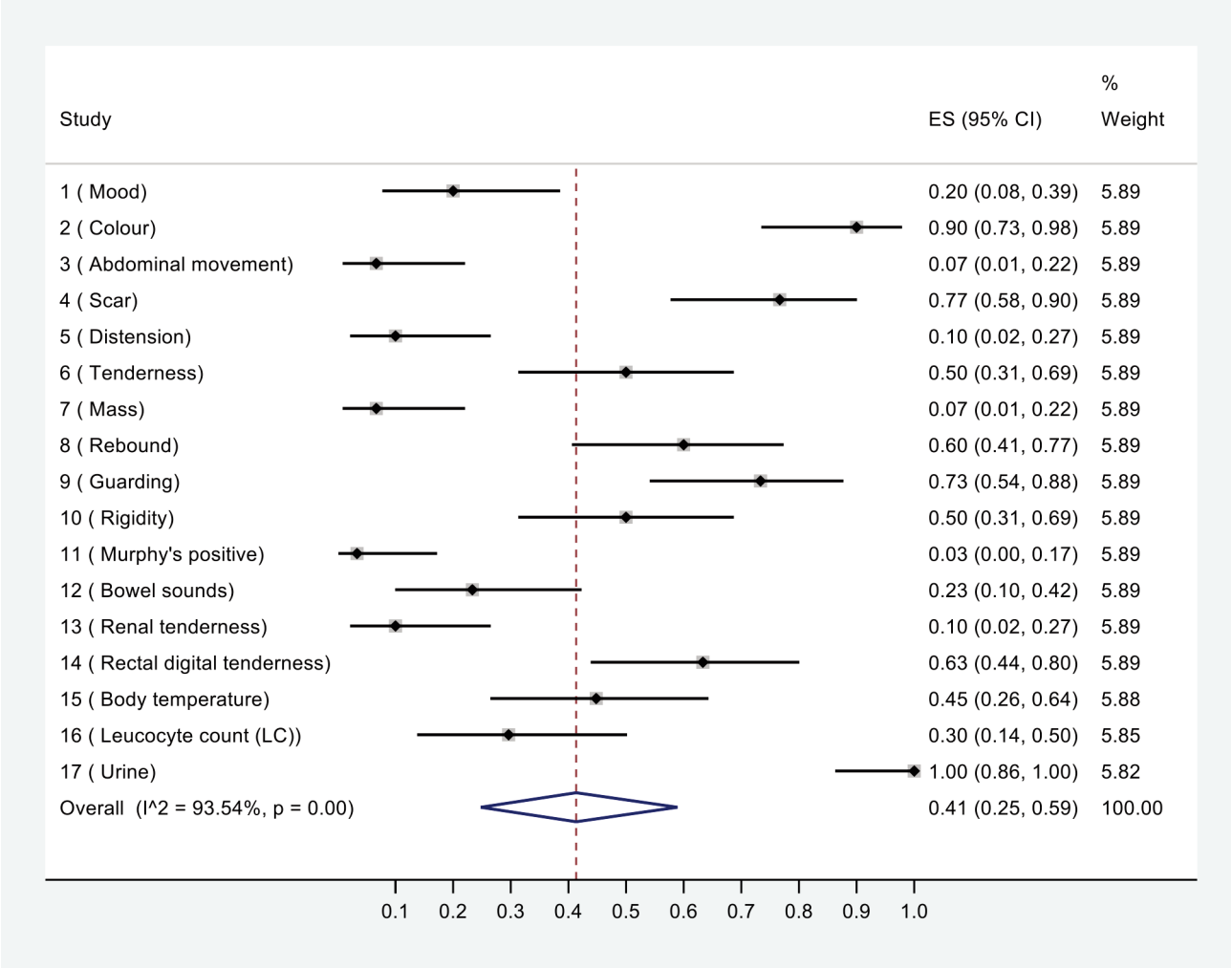

Figure 3. *Sensitivities of signs and tests in acute diverticulitis (AcDi) (random-effects model). ES: Estimated sensitivity; CI: confidence interval.*

unvalidated and most are based on studies with a small sample size (10-15). Lameris *et al.* (10) recorded clinical picture in AAP patients presenting at the ED and identified features associated with AcDi. They developed a DM based on Lab pain, vomiting, and increased CRP. The calculated AUC values of the individual clinical features ranged from 0.51 for diarrhea to 0.74 for CRP. Unfortunately, they did not provide a HSROC analysis for their DM.

Toorenvliet *et al.* (11) assessed 57 patients with AcDi diagnosis to compare the DA of clinical evaluation, abdominal ultrasound (AUS) and computed tomography (CT). They concluded that the DA of the clinical diagnosis for AcDi is low, because the tentative diagnosis of AcDi changed in 37% of their AcDi patients. Although AUS and CT show a higher DA in AcDi, these procedures rarely changed the initial management proposal for the AcDi diagnosis in their study (11). Unfortunately, these authors did not provide any AUC values for the diagnostic tests applied.

Andeweg *et al.* (12) recorded the clinical picture of their AAP patients seen on the ED attempting to find predictors for AcDi and to create a DM. They proposed a DM including 1) the number of previous episodes of AcDi, 2) aggravation of pain, 3) absence of vomiting, 4) Lab pain and 5) CRP >50 mg/l and developed a nomogram using these features. They calculated the AUC values of the individual clinical features in all patients ranging between 0.52 for sex and 0.73 for Lab pain. They did not perform HSROC analysis for their DM or nomogram.

Jamal Talabani *et al.* (13) investigated the DA of AcDi among AAP patients admitted to an ED in Norway. The probability of AcDi was assessed by the examining doctor, using a scale from 0 (zero probability) to 10 (100 % probability). They reached the AUC values for their probability score; AUC=0.95 for AcDi patients <65 years

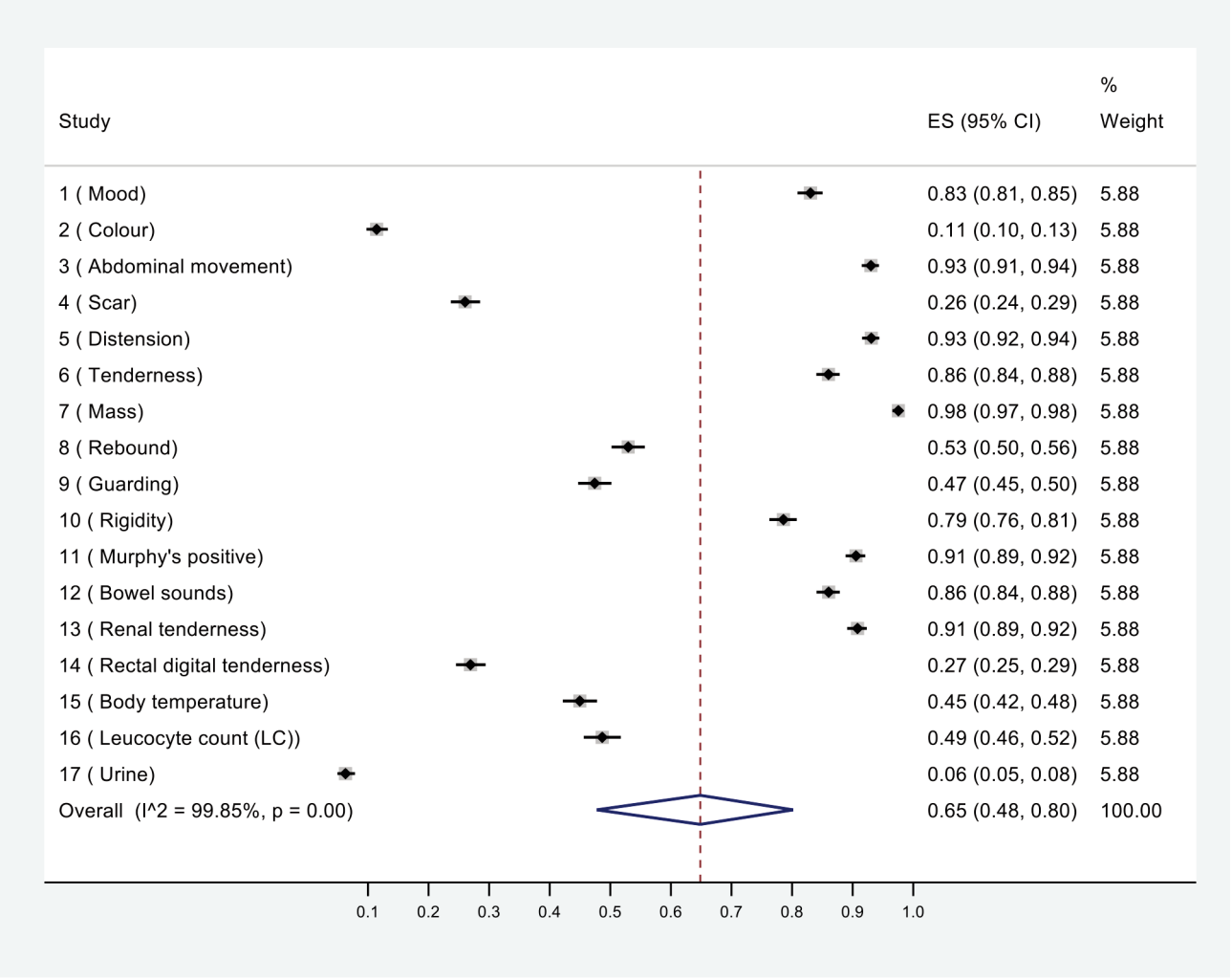

Figure 4. *Specificities of clinical signs and tests in acute diverticulitis (AcDi) (random-effects model). ES: Estimated specificity; CI: confidence interval.*

and AUC=0.86 for older AcDi patients. The AUC values for the laboratory tests in AcDi are ranging from 0.59 for Leuc to 0.83 for CRP. Again, HSROC analysis with AUC values available of the individual clinical features was not made. Albeit that the authors admit that there could be a selection bias due to the ED doctors' awareness of the study, this study demonstrates that clinical evaluation based on symptoms, signs and tests on admission provides a high DA in AcDi patients.

Bolkenstein *et al*. (14) performed a retrospective study including AcDi patients presented at ED. Clinical signs and laboratory parameters were collected and they developed a DM to distinguishing complicated AcDi from uncomplicated AcDi patients. Their DM score included abdominal guarding, CRP level and Leuc. Although, proposed DM could slightly enhance the DA in ruling out complicated AcDi, the laboratory tests needed in this DM includes a significant limitation. Sigurdardottir *et al*. (15) investigated patients with clinical suspicion of AcDi, proposing a DM for AcDi that includes sex, age, urinary symptoms, vomiting, body temperature, CRP, and Lab tenderness. AUC for this DM was 0.82, with the AUC values for the individual clinical features varying from 0.50 for obstipation to 0.65 for CRP (15).

The present study is a comprehensive analysis of the DA in AcDi, by taking into account the role of i) history-taking, ii) examination and iii) laboratory analyses, all used to build up a diagnostic score model for AcDi. As to the symptoms, a special meaning should have abdominal pain, which in AcDi tends to begin in the Lab and often remains in the Lab until the AcDi patient is seen at the hospital. In our study, 40% (12/30) of the AcDi patients had location of initial pain and pain at diagnosis at Lab. The pain of AcDi is sometimes

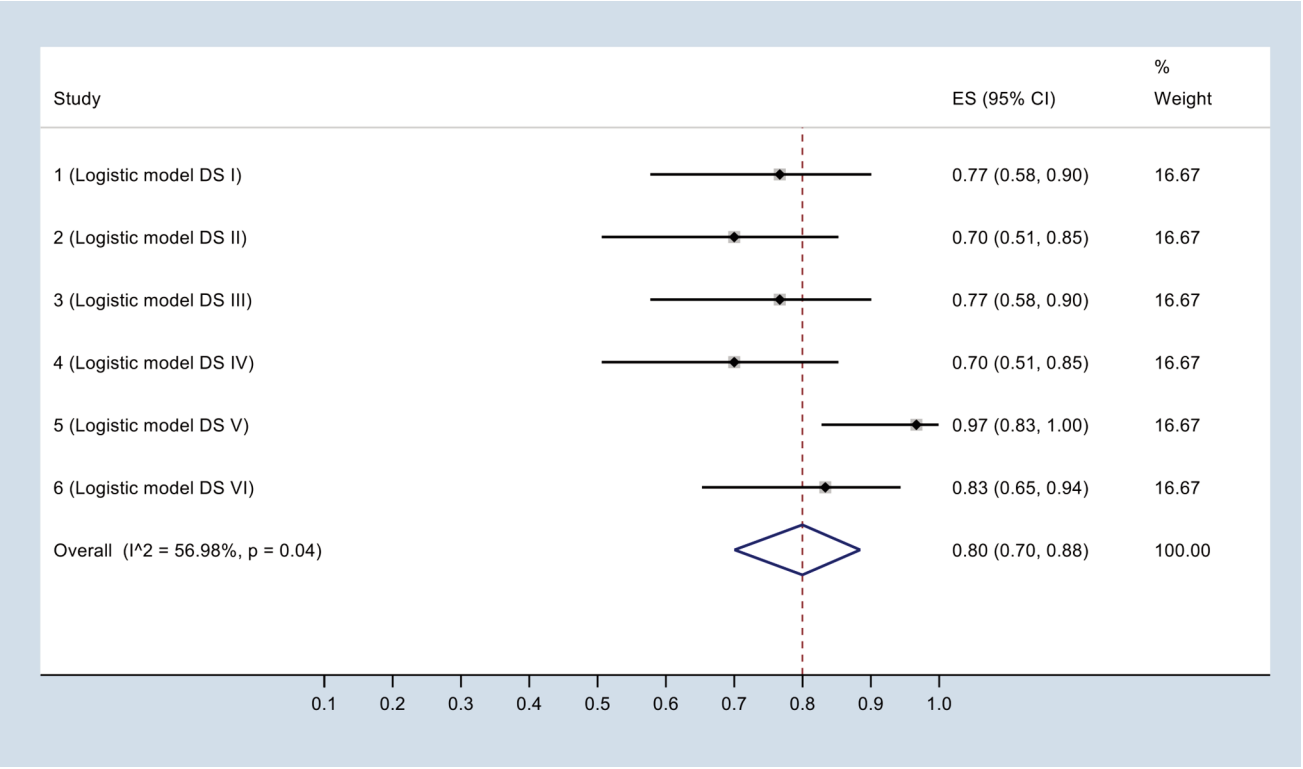

Figure 5. *Sensitivities of diagnostic scores at six different cut-off levels (DS I-VI). ES: Estimated sensitivity; CI: confidence interval.*

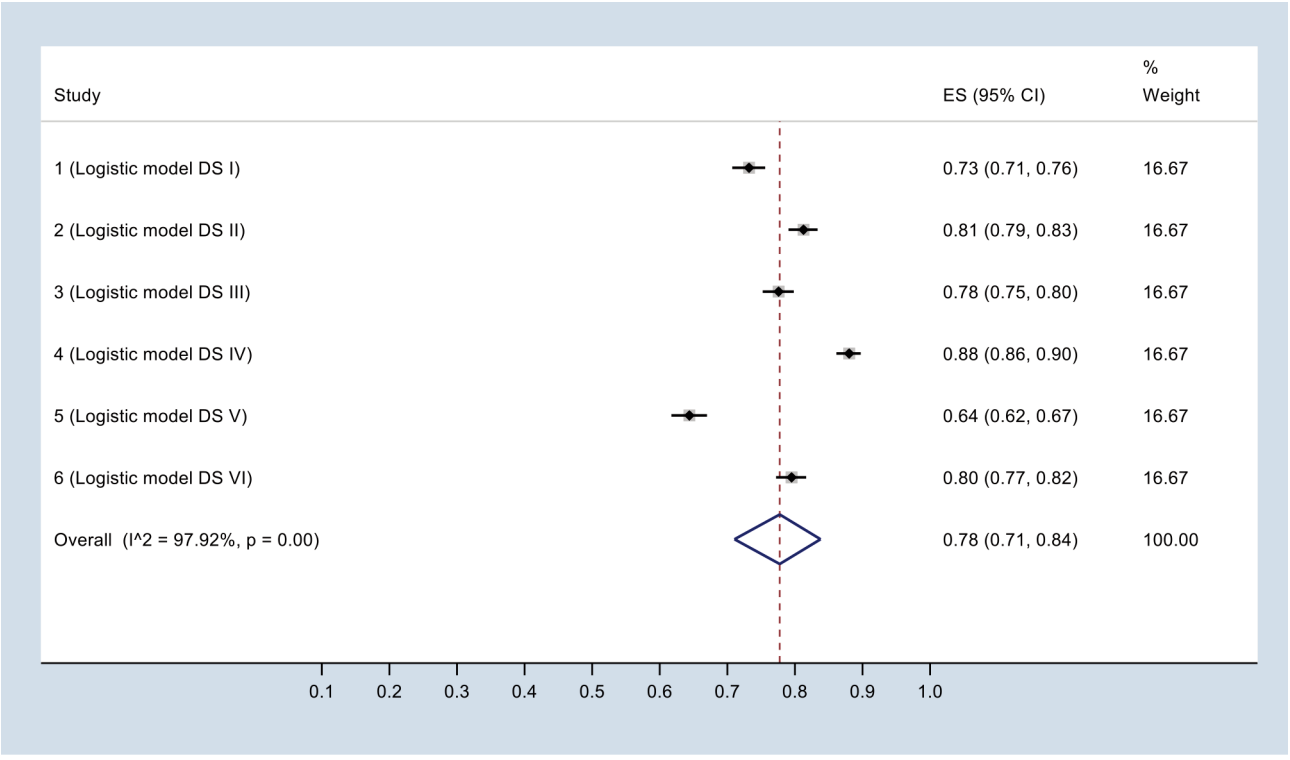

Figure 6. *Specificities of diagnostic scores at six different cut-off levels (DS I-VI). ES: Estimated specificity; CI: confidence interval.*

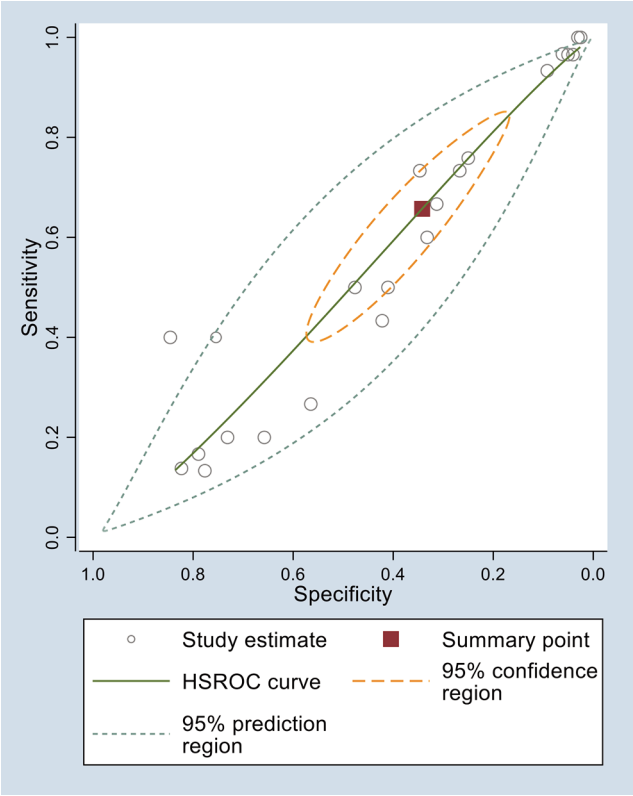

Figure 7. *Hierarchical summary receiver operating characteristic (HSROC) curve of the history-taking in acute diverticulitis (AcDi).*

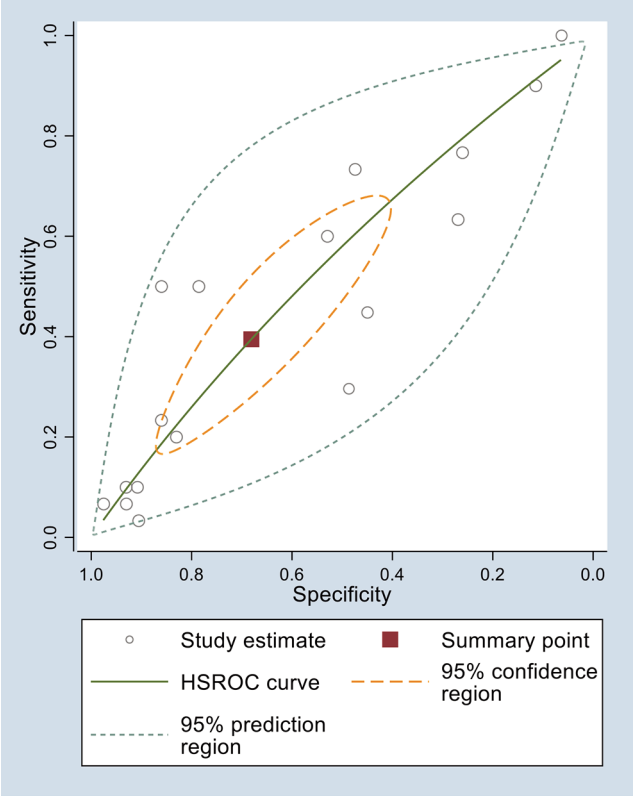

Figure 8. *Hierarchical summary receiver operating characteristic (HSROC) curve of the clinical signs and tests in acute diverticulitis (AcDi).*

quite severe, and in our study 73% (22/30) of AcDi patients had moderate or intolerable pain. One variable important in distinguishing AcDi from peritonitis (Perit) is that the pain in AcDi is mostly steady or intermittent as in 67% (20/30) of patients in this study, whereas this type of pain is rare in Perit. In 20% (6/30) of AcDi patients, the pain is aggravated by movement and this variable does not distinguish AcDi from the Lab diseases such as acute appendicitis or acute small bowel obstruction.

Nausea and vomiting are usually lacking in AcDi. However, the DA of these symptoms has not been considered in AcDi before. In our study, 43% (13/30) of the AcDi patients had nausea and 27% (8/30) had vomiting. Most patients with AcDi have not noticed any abnormality of bowel habits (bowels normal in 26/30) or micturition on admission (micturition normal in 29/30). AcDi tends to be associated with poor appetite. In this investigation, 73% (22/30) of the AcDi patients had positive clinical history of poor or lacking appetite.

The patient with AcDi is unlikely to have a fully non-mobile abdomen at abdominal palpation (Ap). This happens only in about every 13th patient with AcDi in our study (abdominal movement normal 93.3%) (28/30). With regard to tenderness at Ap, half of AcDi patients have Lab tenderness (15/30, 50%), whereas rebound was present in 60% (18/30) of the AcDi patients. Importantly, rigidity was present in half (50%) of the AcDi patients and this is a difference from Perit, where rigidity is a rule rather than exception. On abdominal auscultation, about one fourth (7/30, 23%) of the AcDi patients in our study had abnormal bowel sounds, while the rest of the AcDi patients had bowel sounds, indistinguishable from normal sounds.

In the severity grading of AcDi, there are some formulas that have been used as predictors of organ failure, complications, and survival in AcDi patients (19-21). However, the DMs for patients with AcDi have been rarely evaluated and the DMs with the triage performed at patients' arrival to the ED (triage I) and at follow-up (triage II) before final decision are even more rare.

Meklin *et al*. (18) have recently introduced HSROC analysis in distinguishing DA of traditional and new-generation fecal immunochemical tests used in colorectal cancer screening. Their experience also suggests that HSROC could assist the clinician in differentiating non-

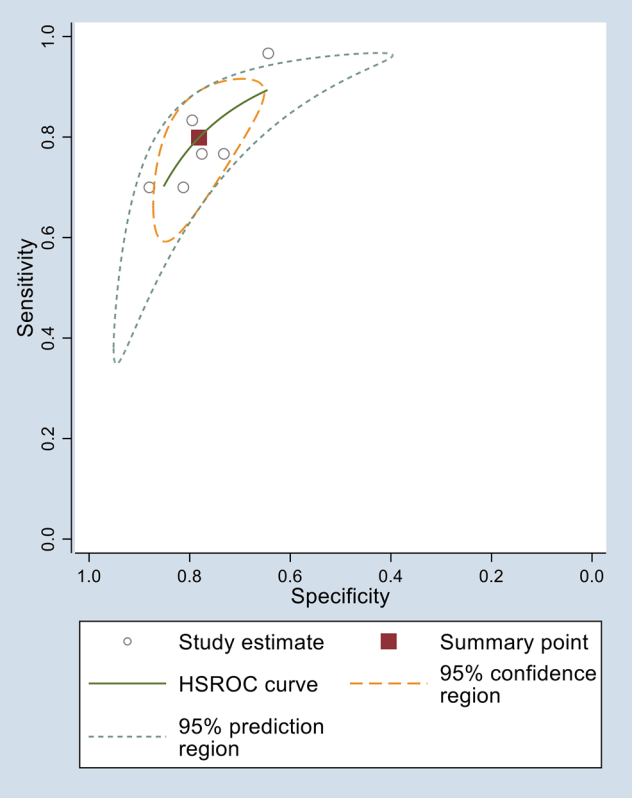

Figure 9. *Hierarchical summary receiver operating characteristic (HSROC) curve of the six diagnostic score models (DMs).*

specific abdominal pain from acute appendicitis (16, 17) and other causes of AAP, and improve the DA in following AAP patients; acute cholecystitis, acute renal colic, acute small bowel obstruction, non-organic dyspepsia, and acute pancreatitis (22-29). The HSROC analysis displays Se as a function of the false positive (FP) rate (1- Sp). HSROC curve for clinical symptoms in AcDi detection almost parallels the diagonal reference line (AUC=0.5) with low AUC value (AUC=0.540) (Figure 7). The DA of the signs & tests is practically similar as that of the clinical symptoms (AUC=0.556) (Figure 8). These data implicate that neither the clinical symptoms nor signs & tests are helpful in diagnosis of AcDi in an ED setting.

The present results clearly confirm that the DMs are highly accurate measures in diagnosing AcDi. As shown in Figure 9, the HSROC curve for the pooled DMs (I-VI), is shifted towards the upper left corner, indicating a significantly better diagnostic accuracy AcDi (AUC=0.853) than obtained by the clinical examination alone. The conventional ROC curves were used for selecting the optimal cut-off points for each DM, *i.e.*, the best balance between Se and Sp. In the present series, the DA of the single DM with two triage (AUC=0.926) was the highest of all DMs, far exceeding that (AUC=0.853) of the HSROC analysis for the pooled DMs in diagnosis of AcDi. Estimating the clinical usefulness of DM formulas for AcDi, we have calculated the usefulness index (UI) (30) for six different formulas. The UI is defined as d×(d-r), where d is the incidence of the finding in the disease (=Se) and r is the incidence of the finding in a reference population (1-Sp). It runs coherently from –1 to 1 and tests where the UI is over 0.35 are regarded as useful (30-33). In the UI analysis of this study, the UI values for the individual DM formulas ranged from 0.357 for DM II to 0.59 for DM V and about 0.45 median UI values were reached in different DM formulas. Taken together, the DM for AcDi performed well considering the simple nature of its structure, but the present AcDi cohort is far too small to draw final conclusions. The results are encouraging enough to warrant a new prospective study with a larger number of AcDi patients, to assess the validity of this DM and to provide additional data for possible revisions of these models.

Conclusion

As confirmed by ROC and HSROC analysis, the new DMs with the triage mode proved to be far superior in their DA for AcDi compared to both symptoms and signs & tests. In the lack of earlier studies, these data report the first evidence that the DM including triage at an ED could improve the detection of AcDi.

Conflicts of Interest

The Authors report no conflicts of interest or financial ties to disclose.

Authors' Contributions

All Authors contributed to the collection and analysis of data, drafting, and revising the manuscript, read and approved the final article.

Acknowledgements

The study was funded by the North Savo Regional Fund (Pohjois-Savon Maakuntarahasto).

References

1 Andeweg CS, Mulder IM, Felt-Bersma RJ, Verbon A, van der Wilt GJ, van Goor H, Lange JF, Stoker J, Boermeester MA, Bleichrodt RP, Netherlands Society of Surgery, Working group from Netherlands Societies of Internal Medicine, Gastroenterologists, Radiology, Health Technology Assessment and Dieticians: Guidelines of diagnostics and treatment of acute left-sided colonic diverticulitis. Dig Surg 30(4-6): 278-292, 2013. DOI: 10.1159/000354035

2 Nagata N, Ishii N, Manabe N, Tomizawa K, Urita Y, Funabiki T, Fujimori S, Kaise M: Guidelines for colonic diverticular bleeding and colonic diverticulitis: Japan Gastroenterological Association. Digestion 99 Suppl 99(Suppl. 1): 1-26, 2019. DOI: 10.1159/000495282

3 Raña-Garibay R, Salgado-Nesme N, Carmona-Sánchez R, Remes-Troche JM, Aguilera-Carrera J, Alonso-Sánchez L, Arnaud-Carreño C, Charúa-Guindic L, Coss-Adame E, de la Torre-Bravo A, Espinosa-Medina D, Esquivel-Ayanegui F, Roesch-Dietlen F, López-Colombo A, Muñoz-Torres JI, Noble-Lugo A, Rojas-Mendoza F, Suazo-Barahona J, Stoopen-Rometti M, Torres-Flores E, Vallejo-Soto M, Vergara-Fernández O: The Mexican consensus on the diagnosis and treatment of diverticular disease of the colon. Rev Gastroenterol Mex (Engl Ed) 84(2): 220-240, 2019. DOI: 10.1016/j.rgmx.2019.01.002

4 Sartelli M, Weber DG, Kluger Y, Ansaloni L, Coccolini F, Abu-Zidan F, Augustin G, Ben-Ishay O, Biffl WL, Bouliaris K, Catena R, Ceresoli M, Chiara O, Chiarugi M, Coimbra R, Cortese F, Cui Y, Damaskos D, De' Angelis GL, Delibegovic S, Demetrashvili Z, De Simone B, Di Marzo F, Di Saverio S, Duane TM, Faro MP, Fraga GP, Gkiokas G, Gomes CA, Hardcastle TC, Hecker A, Karamarkovic A, Kashuk J, Khokha V, Kirkpatrick AW, Kok KYY, Inaba K, Isik A, Labricciosa FM, Latifi R, Leppäniemi A, Litvin A, Mazuski JE, Maier RV, Marwah S, McFarlane M, Moore EE, Moore FA, Negoi I, Pagani L, Rasa K, Rubio-Perez I, Sakakushev B, Sato N, Sganga G, Siquini W, Tarasconi A, Tolonen M, Ulrych J, Zachariah SK, Catena F: 2020 update of the WSES guidelines for the management of acute colonic diverticulitis in the emergency setting. World J Emerg Surg 15(1): 32, 2020. DOI: 10.1186/s13017-020-00313-4

5 Fugazzola P, Ceresoli M, Coccolini F, Gabrielli F, Puzziello A, Monzani F, Amato B, Sganga G, Sartelli M, Menichetti F, Puglisi GA, Tartaglia D, Carcoforo P, Avenia N, Kluger Y, Paolillo C, Zago M, Leppäniemi A, Tomasoni M, Cobianchi L, Dal Mas F, Improta M, Moore EE, Peitzman AB, Sugrue M, Agnoletti V, Fraga GP, Weber DG, Damaskos D, Abu-Zidan FM, Wani I, Kirkpatrick AW, Pikoulis M, Pararas N, Tan E, Broek RT, Maier RV, Davies RJ, Kashuk J, Shelat VG, Mefire AC, Augustin G, Magnone S, Poiasina E, De Simone B, Chiarugi M, Biffl W, Baiocchi GL, Catena F, Ansaloni L: The WSES/SICG/ACOI/SICUT/AcEMC/SIFIPAC guidelines for diagnosis and treatment of acute left colonic diverticulitis in the elderly. World J Emerg Surg 17(1): 5, 2022. DOI: 10.1186/s13017-022-00408-0

6 Sebastián-Tomás JC, Gómez-Abril SA, Ripollés T, Manrique A, Torres-Sanchez T, Martínez-Pérez MJ: How to strengthen the management of acute diverticulitis: the utility of the WSES classification—a prospective single-center observational study. Eur J Trauma Emerg Surg 48(5): 4283-4291, 2022. DOI: 10.1007/s00068-022-01911-4

7 Qaseem A, Etxeandia-ikobaltzeta I, Lin JS, Fitterman N, Shamliyan T, Wilt TJ, Clinical Guidelines Committee of the American College of Physicians: Diagnosis and management of acute left-sided colonic diverticulitis: a clinical guideline from the American College of Physicians. Ann Intern Med 175(3): 399-415, 2022. DOI: 10.7326/M21-2710

8 Kruis W, Germer CT, Böhm S, Dumoulin FL, Frieling T, Hampe J, Keller J, Kreis ME, Meining A, Labenz J, Lock JF, Ritz JP, Schreyer A, Leifeld L, German Society of Gastroenterology, Digestive and Metabolic Diseases (DGVS) and the German Society of General and Visceral Surgery (DGAV) (AWMF-Register 021-20): German guideline diverticular disease/diverticulitis: Part I: Methods, pathogenesis, epidemiology, clinical characteristics (definitions), natural course, diagnosis and classification. United European Gastroenterol J 10(9): 923-939, 2022. DOI: 10.1002/ueg2.12309

9 Calini G, Abd El Aziz MA, Paolini L, Abdalla S, Rottoli M, Mari G, Larson DW: Symptomatic uncomplicated diverticular disease (SUDD): Practical guidance and challenges for clinical management. Clin Exp Gastroenterol 16: 29-43, 2023. DOI: 10.2147/CEG.S340929

10 Laméris W, van Randen A, van Gulik TM, Busch OR, Winkelhagen J, Bossuyt PM, Stoker J, Boermeester MA: A clinical decision rule to establish the diagnosis of acute diverticulitis at the emergency department. Dis Colon Rectum 53(6): 896-904, 2010. DOI: 10.1007/DCR.0b013e3181d98d86

11 Toorenvliet BR, Bakker RFR, Breslau PJ, Merkus JWS, Hamming JF: Colonic diverticulitis: a prospective analysis of diagnostic accuracy and clinical decision-making. Colorectal Dis 12(3): 179-186, 2010. DOI: 10.1111/j.1463-1318.2009.01778.x

12 Andeweg CS, Knobben L, Hendriks JCM, Bleichrodt RP, van Goor H: How to diagnose acute left-sided colonic diverticulitis. Ann Surg 253(5): 940-946, 2011. DOI: 10.1097/SLA.0b013e3182113614

13 Jamal Talabani A, Endreseth BH, Lydersen S, Edna TH: Clinical diagnostic accuracy of acute colonic diverticulitis in patients admitted with acute abdominal pain, a receiver operating characteristic curve analysis. Int J Colorectal Dis 32(1): 41-47, 2017. DOI: 10.1007/s00384-016-2644-0

14 Bolkenstein HE, Van De Wall BJ, Consten EC, Van Der Palen J, Broeders IA, Draaisma WA: Development and validation of a diagnostic prediction model distinguishing complicated from uncomplicated diverticulitis. Scandinavian Journal of Gastroenterology 53(10-11): 1291-1297, 2018. DOI: 10.1080/00365521.2018.1517188

15 Sigurdardottir J, Chabok A, Wagner P, Nikberg M: Increased accuracy in diagnosing diverticulitis using predictive clinical factors. Ups J Med Sci 127: e8803, 2022. DOI: 10.48101/ujms.v127.8803

16 Meklin J, Eskelinen M, Syrjänen K, Eskelinen M: Leucocyte count does not improve the diagnostic performance of a diagnostic score (DS) in distinguishing acute appendicitis (AA) from nonspecific abdominal pain (NSAP). In Vivo 34(6): 3327-3339, 2020. DOI: 10.21873/invivo.12171

17 Meklin J, Eskelinen M, Syrjänen K, Eskelinen M: Gender-specific performance of a diagnostic score in acute appendicitis. In Vivo 34(6): 3687-3703, 2020. DOI: 10.21873/invivo.12217

18 Meklin J, Syrjänen K, Eskelinen M: Fecal occult blood tests in colorectal cancer screening: systematic review and meta-analysis of traditional and new-generation fecal immunochemical tests. Anticancer Res 40(7): 3591-3604, 2020. DOI: 10.21873/anticanres.14349

19 Constantinides VA, Tekkis PP, Athanasiou T, Aziz O, Purkayastha S, Remzi FH, Fazio VW, Aydin N, Darzi A, Senapati A: Primary resection with anastomosis *vs*. Hartmann's procedure in nonelective surgery for acute colonic diverticulitis: a systematic review. Dis Colon Rectum 49(7): 966-981, 2006. DOI: 10.1007/s10350-006-0547-9

20 Sartelli M, Moore FA, Ansaloni L, Di Saverio S, Coccolini F, Griffiths EA, Coimbra R, Agresta F, Sakakushev B, Ordoñez CA, Abu-Zidan FM, Karamarkovic A, Augustin G, Costa Navarro D, Ulrych J, Demetrashvili Z, Melo RB, Marwah S, Zachariah SK, Wani I, Shelat VG, Kim JI, McFarlane M, Pintar T, Rems M, Bala M, Ben-Ishay O, Gomes CA, Faro MP, Pereira GA Jr, Catani M, Baiocchi G, Bini R, Anania G, Negoi I, Kecbaja Z, Omari AH, Cui Y, Kenig J, Sato N, Vereczkei A,

Skrovina M, Das K, Bellanova G, Di Carlo I, Segovia Lohse HA, Kong V, Kok KY, Massalou D, Smirnov D, Gachabayov M, Gkiokas G, Marinis A, Spyropoulos C, Nikolopoulos I, Bouliaris K, Tepp J, Lohsiriwat V, Çolak E, Isik A, Rios-Cruz D, Soto R, Abbas A, Tranà C, Caproli E, Soldatenkova D, Corcione F, Piazza D, Catena F: A proposal for a CT driven classification of left colon acute diverticulitis. World J Emerg Surg 10: 3, 2015. DOI: 10.1186/1749-7922-10-3

21 Ferrara F, Guerci C, Bondurri A, Spinelli A, De Nardi P, indexed collaborators: Emergency surgical treatment of colonic acute diverticulitis: a multicenter observational study on behalf of the Italian society of colorectal surgery (SICCR) Lombardy committee. Updates Surg 75(4): 863-870, 2023. DOI: 10.1007/s13304-023-01487-7

22 Eskelinen M, Meklin J, Syrjänen K, Eskelinen M: Performance of a diagnostic score in confirming acute cholecystitis among patients with acute abdominal pain. Anticancer Res 40(12): 6947-6956, 2020. DOI: 10.21873/anticanres.14719

23 Eskelinen M, Meklin J, Syrjänen K, Eskelinen M: Pediatric acute appendicitis score in children with acute abdominal pain (AAP). Anticancer Res 41(1): 297-306, 2021. DOI: 10.21873/anticanres.14776

24 Eskelinen M, Meklin J, Syrjänen K, Eskelinen M: A diagnostic score (DS) is a powerful tool in diagnosis of acute appendicitis in elderly patients with acute abdominal pain. Anticancer Res 41(3): 1459-1469, 2021. DOI: 10.21873/anticanres.14904

25 Eskelinen M, Meklin J, Syrjänen K, Eskelinen M: A diagnostic score for acute small bowel obstruction. Anticancer Res 41(4): 1959-1970, 2021. DOI: 10.21873/anticanres.14963

26 Eskelinen M, Meklin J, Syrjänen K, Eskelinen M: A diagnostic score for reliable confirmation of acute renal colic among patients with acute abdominal pain. Anticancer Res 41(6): 3045-3054, 2021. DOI: 10.21873/anticanres.15087

27 Eskelinen M, Meklin J, Selander T, Syrjänen K, Eskelinen M: A diagnostic score (DS) in the difficult diagnosis of non-specific abdominal pain (NSAP). In Vivo 35(5): 2729-2738, 2021. DOI: 10.21873/invivo.12557

28 Eskelinen M, Meklin J, Selander T, Syrjänen K, Eskelinen M: History-taking, clinical signs, tests and scores for detection of non-organic dyspepsia (NOD) among patients with acute abdominal pain (AAP). Cancer Diagn Progn 1(4): 265-274, 2021. DOI: 10.21873/cdp.10034

29 Eskelinen M, Meklin J, Selander T, Syrjänen K, Eskelinen M: A simple prediction score for diagnosis of acute pancreatitis. In Vivo 36(5): 2287-2296, 2022. DOI: 10.21873/invivo.12958

30 Eskelinen M, Lipponen P: Usefulness of history-taking in non-specific abdominal pain: a prospective study of 1333 patients with acute abdominal pain in Finland. In Vivo 26(2): 335-339, 2012.

31 Eskelinen M, Lipponen P: Usefulness index in nonspecific abdominal pain-an aid in the diagnosis? Scand J Gastroenterol 47(12): 1475-1479, 2012. DOI: 10.3109/00365521.2012.733951

32 Eskelinen M, Selander T, Lipponen P, Juvonen P: History-taking and the usefulness index in the diagnosis of functional dyspepsia. Isr Med Assoc J 16(8): 497-501, 2014.

33 Lavelle S, Kanagaratnam B: The information value of clinical data. Int J Biomed Comput 26(3): 203-209, 1990. DOI: 10.1016/0020-7101(90)90043-t

Received June 29, 2023
Revised July 27, 2023
Accepted August 28, 2023