Validation of peritoneal adhesion index as a standardized classification to universalize peritoneal adhesions definition

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Abstract

Peritoneal adhesion index (PAI) is a score based on appearance and distribution of peritoneal adhesions. The study aims to assess the validity of PAI in order to standardize the definition of peritoneal adhesions.

The study includes an expert survey to assess the feasibility of the score and a prospective observational and multicenter trial to assess its validity. 96% of surgeons of the survey consider PAI a useful tool. From January 2013 to March 2015, 205 patients were enrolled to undergo a surgical intervention for bowel obstruction caused by peritoneal adhesions in 21 centers. PAI was significantly higher in the population with previous surgery (P=0.043) and in patients who underwent two previous surgical interventions, if compared to those with only one previous intervention (P=0.012). Length of surgery was significantly longer in patients with higher PAI (P<0.001). Patients with a higher PAI showed a clinically higher risk for early bowel re-obstruction and for early re-intervention. The AUC of the ROC curve for early re-occlusion is 0.8. PAI can be considered a feasible and useful score.

Introduction

Bowel obstruction due to peritoneal adhesions is a major surgical problem. Adhesions occur after 50-100% of surgical interventions.[1,2] They are often responsible for small bowel obstructions,[3,4] secondary female infertility, ectopic gestation[5,6] and chronic abdominal pains.[7-9] The impact of adhesions on surgeon workload and on the healthcare cost is significant. As a matter of fact, in the USA in 1996 the total annual cost for adhesions management exceeded $ 2 billion.[10,11] Therefore, different classification systems were suggested,[12,13] however they did not provide the univocal definition for adhesions under both a quantitative and a qualitative point of view. At present it is not possible to analytically standardize adhesions. Coccolini *et al.* proposed a classification of adhesions aiming to universalize their definition.[14] This index is based on the macroscopic appearance of adhesions and on their diffusion to the different abdominal zones. It allows to obtain a peritoneal adhesion index (PAI) ranging from 0 to 30 and to give a precise definition of the intra-abdominal situation. Sisodia *et al*. in a recent prospective observational, cross sectional study on 30 patients, stated that PAI is a sensitive tool in patients with adhesive intestinal obstruction.[2] The aim of this study is to validate PAI score by assessing its feasibility, demonstrating its correlation with preoperative conditions and intraoperative findings and evaluating its reliability in predicting postoperative outcomes.

Materials and Methods

The PAI score is shown in Figure 1.[14] The study is divided into two phases. The first one concerns an expert survey to assess the feasibility of the score. While the second phase assesses its validity through a prospective, observational and multicenter trial.

Survey

The PAI score feasibility was tested through a questionnaire addressed to fifty-one surgeons from twenty-one different hospital centers. By taking part in this survey, all the fifty-one surgeons had to answer to the following three questions:

Question 1: Do you consider the proposed score useful?

Question 2: Do you consider the score applicable to all patients with peritoneal adhesions?

Question 3: Do you consider the score applicable by all the surgeons?

Trial

The validity of the score was assessed by a prospective, observational, multicenter trial. 205 patients were enrolled. All patients underwent a surgical intervention for bowel obstruction, caused by peritoneal adherences. Surgical interventions were performed in sixteen centers between January 2013 and March 2015. All preoperative characteristics, intraoperative features and postoperative outcomes were registered for each patients.

We challenged the subsequent hypothesis:

Hypothesis 1: PAI score is related to pre-operative features;

Hypothesis 2: PAI score is related to intra-operative features;

Hypothesis 3: PAI score is related to operative time;

Hypothesis 4: PAI score is related to post-operative outcome;

ROC curve analysis: The sensitivity and specificity of the PAI score was investigated using receiver operating characteristic (ROC) curve methodology. A positive case was defined as an early episode of re-occlusion.

Differences among continuous variables across groups were evaluated by the Student's *t* test or by the ANOVA test. Statistical analysis was done by IBM SPSS Statistics.

Results

Survey

Figure 2 shows the volume of surgical interventions and the volume of intestinal adhesion complications, managed by each center involved in this study.

Here below answers to the questionnaires are considered.

Question 1: 96% (49/51) of the surgeons believe that PAI is useful (Figure 2);

Question 2: 88% (44/51) of the surgeons consider PAI applicable to all patients with peritoneal adhesions (Figure 2);

Question 3: 84% (43/51) of the surgeons consider PAI applicable by all surgeons (Figure 2).

Trial

The descriptive statistic is reported in Table 1. Figure 3 shows the body regions where patients undergoing bowel obstruction surgery had adherences. 66.7% of the patients had adhesions in central abdominal region and 61.3% had bowel to bowel adherences. 79% of patients had a history of previous abdominal surgery (emergency and elective surgery in 42.3% and 50% of patients respectively). Most of patients had a previous colorectal and upper GI intervention (43.7% and 25.3%). 94.4% of patients with history of previous surgery had a previous laparotomy, while 5.7% had only previous laparoscopic interventions. 23.6% had previous peritonitis and 26.3% had previous bowel obstruction. Mean and median PAI of patients undergoing surgical intervention for peritoneal adhesion complication were 9.5±8.9 and 6 (1-30) respectively. For 32.1% of patients, a bowel resection was necessary during surgical intervention. However only in 6.5% of the cases, necrotic bowel was found. Postoperative morbidity was 28.9%. Among patients having a postoperative complication, 10% had a cardiovascular complication, 45% a pulmonary problem, 5% a deep abscess, 25% an enteric fistula and 15% a wound infection. Postoperative mortal-

ity was 11.5%. Re-intervention rate was 9.7% and bowel re-obstruction during the first month happened in 20% of patients.

Hypothesis 1: Total PAI score was significantly higher in the population with previous surgery (PAI score 7.64±8.89 *vs* 12.7±10.49, P=0.043). Furthermore, PAI is higher in patients who underwent two previous surgical interventions, if compared to those with only one previous intervention (13.72±7.28 *vs* 8.21±5.86, P=0.012). There is not significant difference between PAI score in patients with 2 *Vs*. ≥3 previous interventions (P=0.997) (Table 2).

Linear regression showed a coefficient of 1.91±0.79, P=0.017 (Figure 4).

Patients with previous colorectal and upper GI surgery had a higher PAI score than those with previous gynecological and trauma surgery. However, there is not any statistical significant difference (P=0.092) (Table 2).

PAI score does not show any significant differences when the following characteristics are taken into consideration: previous surgical access (open *vs* laparoscopic, P=0.352), previous surgical setting (emergency *vs* elective, p=0.120), history of previous peritonitis (P=0.531), previous bowel obstruction (P=0.302) and patient ASA score (P=0.150) (Table 2).

Hypothesis 2: Patients needing bowel resection had a higher PAI than those that did not. However statistical difference is not significant (12.72±9.72 *vs* 9.57±8.76, P=0.058) (Table 2).

There was no difference in PAI score based on the presence of necrotic bowel (P=0.653) (Table 2).

Hypothesis 3: Length of surgery was statistically and clinically significantly longer in patients with higher PAI score (P<0.001) (Table 2). Linear regression showed a coefficient of 0.056±0.009, P<0.001 (Figure 4).

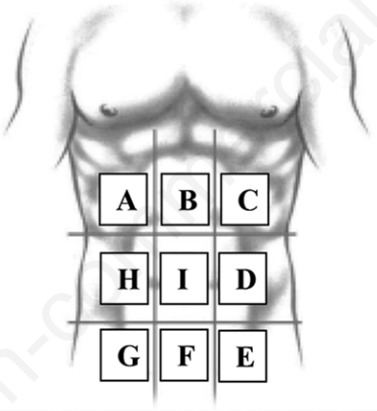
Hypothesis 4: Patients with an higher PAI showed a higher, but not statistically significant, risk for early bowel re-obstruction (19.16±12.23 *vs* 7.91±7.25, P=0.075) and for early re-intervention (16.26±11.42 *vs* 10.64±8.34, P=0.083) (Table 2).

There were not any differences in PAI score in patients with postoperative complications (P=0.285) and with postoperative death (P=0.648) (Table 2).

ROC analysis: ROC curve for PAI score and the risk for early bowel re-occlusion is reported in Figure 5. The AUC is 0.8 and the PAI best cut-off is 9.

Discussion

The main issues in presenting a new score are related to applicability, clinical reliability and easiness of use. Moreover its correspondence to treatment pathway and outcomes is mandatory. Expert survey stated the feasibility of PAI score because PAI is



Regions		Adhesion grade
A	Right upper	____
B	Epigastrium	____
C	Left upper	____
D	Left flank	____
E	Left lower	____
F	Pelvis	____
G	Right lower	____
H	Right flank	____
I	Central	____
L	Bowel to bowel	____

PAI ☐

Adhesion grade score	
0	No adhesions
1	Filmy adhesions, blunt dissection
2	Strong adhesions, sharp dissection
3	Very strong vascularized adhesions, sharp dissection, damage hardly preventable

Figure 1. Peritoneal adhesion index (PAI).

applicable to all patients with peritoneal adhesions (agreement of 88%) and by all the surgeons (agreement of 84%). Furthermore 96% of surgeons consider PAI a useful tool.

Patients undergoing a surgical intervention for peritoneal adhesions bowel obstruction have a mean PAI of 9.5±8.9. As demonstrated by Sisodia *et al*.,[2] the causes for most parts of bowel obstructions are central abdominal (66.7%) and bowel to bowel adhesions (61.3%).

Regarding pre-operative characteristics, most patients (79%) had a history of previous abdominal surgery and total PAI score was significantly higher in the population with previous surgery (7.64±8.89 *vs* 12.7±10.49, P=0.043). Contrary to what shown in the study by Sisodia *et al*.,[2] PAI is higher in patients with two previous surgical interventions than in those with only one previous operation (8.21±5.86 *vs* 13.72±7.28, P=0.012). Linear regression showed a coefficient of 1.91±0.79, P=0.017 (Figure 4). DeCherney and DiZerega[15,16] reported that the problem of postsurgical adhesions increases with the number of previous laparotomies, while other authors stated that the increase of peritoneal adhesions due to multiple surgical procedures does not correlate to the risk of bowel obstruction.[17] Probably the different results may be due to the poor accuracy of the index used to evaluate adhesions. According to present data, patients with one and two previous surgical procedures have an increasing number of adhesions and a consequently higher risk of bowel obstruction.

Similarly to other studies[2,10,18] gastrointestinal surgery is the kind of surgery that may most frequently cause intra-abdominal adhesions. In fact many patients of this study presented a history of colorectal and upper GI surgery (43.7% and 25.3%). According to Sisodia *et al*.[2] patients with previous colorectal and upper GI surgery had also a higher PAI score than those with previous gynecological and trauma surgery, but there is not any statistical significant difference (P=0.092).

In literature there is not agreement regarding the different rates of adhesion formation and bowel obstruction due to peritoneal adhesions, following a laparotomy *vs* a laparoscopic intervention.[17,19-26] In this study most patients (94.4%) have a history of laparotomy. However there are not significant differences in PAI score based on previous surgical access (open *vs* laparoscopic, P=0.352). On the one hand in some studies laparoscopy in gastrointestinal surgery was reported to reduce the adhesion formation rate by 25% and to decrease the adhesion severity score,[10] but the level of evidence is low.[17] On the other hand, the incidence of adhesion-related post-operative obstruction was studied in two randomized prospective trials. By comparing laparotomy and laparoscopy for colorectal surgery statistically significant differences were not found.[17,27,28] Most probably the theoretical advantages of laparoscopy did not show a correspondent decrease in the risk for bowel obstruction.[17] Furthermore there is some evidence in literature demonstrating that pneumoperitoneum enhances adhesion formation, by increasing hypoxia and by releasing vascular endothelial growth factor.[10,17]

Contrary to what was found by some authors,[29] PAI score did not show any difference in this study, when the following characteristics were analyzed: previous surgical setting (emergency *vs* elective, P=0.120), history of previous peritonitis (P=0.531), previous bowel obstruction (P=0.302). There are not even differences based on ASA score (P=0.150).

Regarding intraoperative finding, the need for bowel resection is more likely in patients with higher PAI, but there is not any statistical significant correlation (12.72±9.72 *vs* 9.57±8.76, P=0.058).

PAI can provide an idea of the surgical complexity of the adhesiolysis. In fact, length of surgery was longer in patients with higher PAI score (P<0.001). Besides, linear regression showed a coefficient of 0.056±0.009 (P<0.001).

Regarding postoperative outcomes, patients that had higher PAI showed a higher, but not statistically significant, risk for early bowel re-obstruction (19.16±12.23 *vs* 7.91±7.25, P=0.075) and risk for early re-intervention (16.26±11.42 *vs* 10.64±8.34, P=0.083).

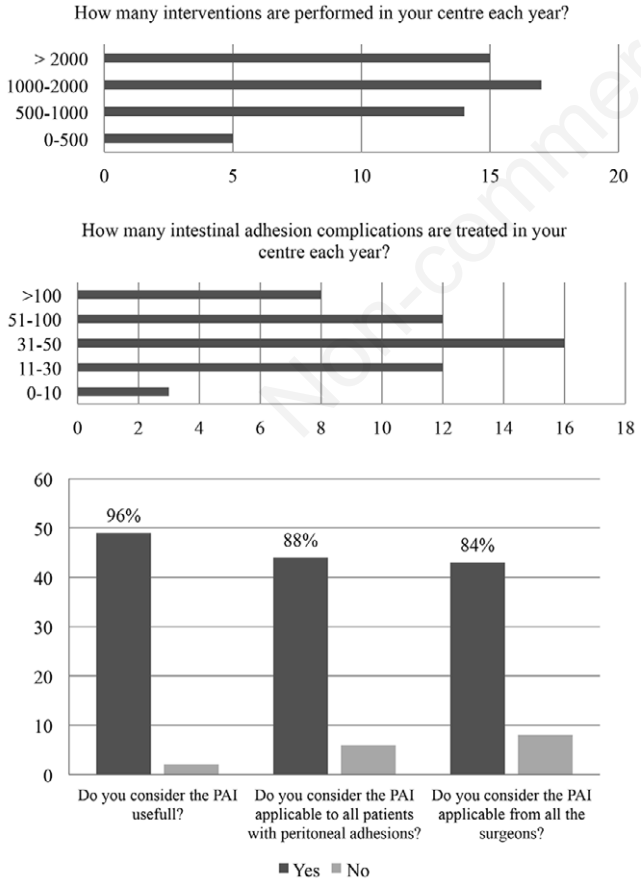


Figure 2. Features of the centers involved in survey and survey centers answers.

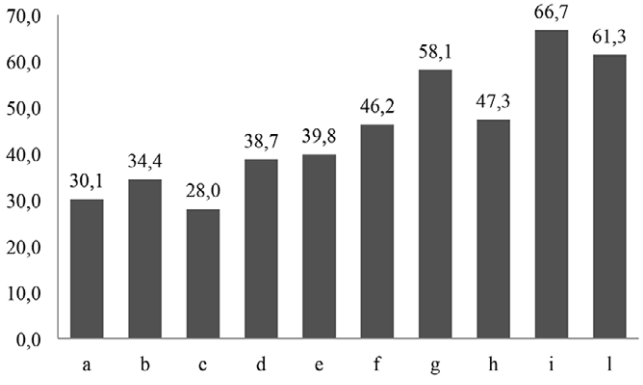


Figure 3. Distribution of body regions where patients undergoing bowel obstruction surgery have adherences. a, right upper region; b, epigastrium region; c, left upper region; d, left flank region; e, left lower region; f, pelvis; g, right lower region; h, right flank region; i, central region; l, bowel to bowel adherences.

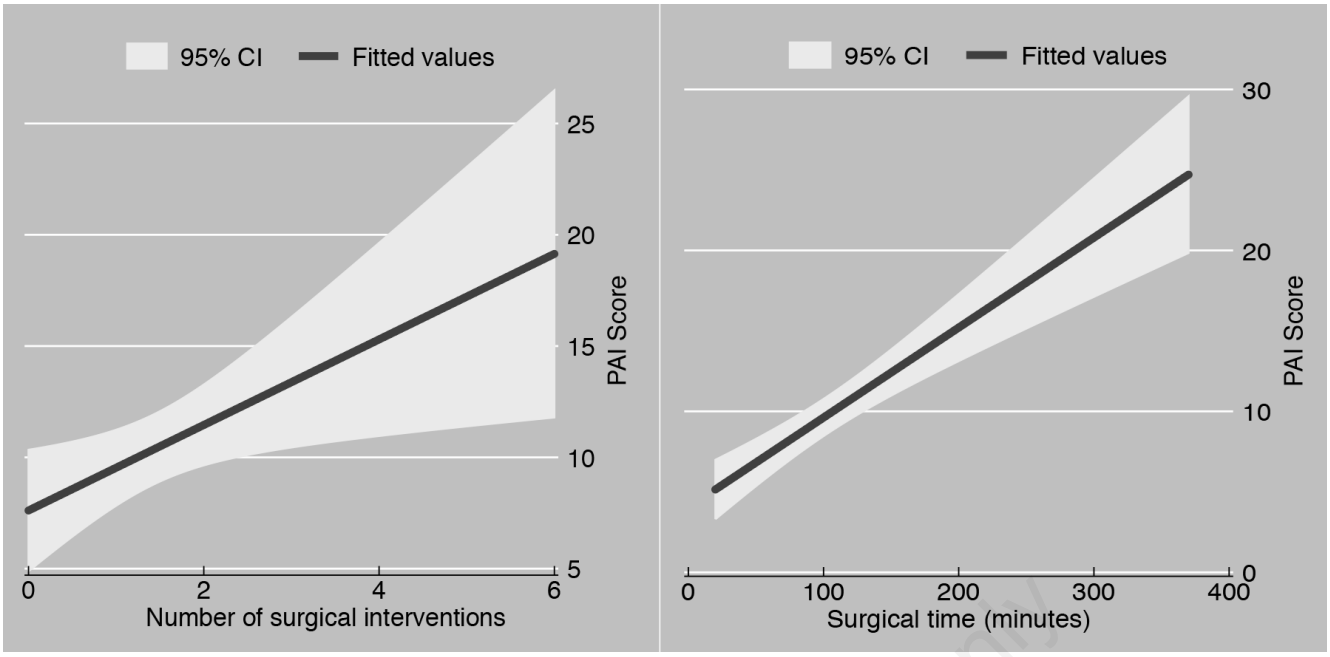


Figure 4. Regress with 95% CI of PAI score against number of previous surgical procedure (P=0.017) and against length of surgical procedure in minutes (P<0.001).

Table 1. Pre-, intra- and post-operative patients characteristics (n=205).

Preoperative characteristics	
Male/Female	50.7%/49.3%
Age	60.9±19.5; 67 [8-95]
ASA I/II/III/IV	27.8%/34.9%/31.3%/6.0%
Previous abdominal surgery	79.0%
Number of previous surgical interventions	1.6±1.5; 1 [0 - 7]
Previous peritonitis	23.6%
Previous surgery settings (emergency/elective/both)	42.3%/50.0%/7.7%
Type of previous surgery (upper GI/colorectal/gynecological/trauma)*	25.3%/43.7%/18.3%/12.7%
Access to previous surgery (open/laparoscopic/both)	90.0%/5.7%/4.3%
Previous intestinal obstruction	26.3%
Intraoperative characteristics	
PAI	9.5±8.9; 6 [1-30]
Operative duration	101.4±65.5; 90 [20-370]
Peritonitis	13.0%
Fecal/enteral contamination	3.9%
Presence of necrotic bowel	6.5%
Bowel resection	32.1%
Use of preventive measures to reduce adhesions	13.2%
Postoperative characteristics	
ICU admission	16.7%
Postoperative complications	28.9%
Reintervention	9.7%
Perioperative death	11.5%
Early bowel re-obstruction	20%

Categorical variables are expressed as percentages of the total, continuous variables are expressed as media±SD; median [min-max]. PAI, peritoneal adhesions index; ICU, intensive care units; ASA, American Society of Anaesthesiologists score; Upper GI, upper gastro intestinal. *Each patient can have been subjected to more than one surgical intervention type.

According to the ROC curve, PAI can be considered a moderately accurate test to predict early bowel re-obstruction (AUC=0.8). The best PAI cut-off is 9.

PAI score is not in correlation with postoperative morbidity (P=0.285) and mortality (P=0.648). Probably because patients' comorbidities and performance status play a more important role in influencing these outcomes.

Therefore, as already demonstrated by Sisodia *et al.*,[2] PAI can be considered a reliable score to standardize adhesion evaluation. As PAI is correlated both to preoperative patient features and intra- and postoperative outcomes, it can give us a fairy accurate idea of the severity of the clinical situation. Furthermore it can be easily used in comparative studies, to evaluate how to avoid the formation of adhesions and to prevent

Table 2. Relationship between PAI and pre-, intra- and post-operative events.

	Mean	SD	Median	Min	Max
Type of previous surgery (P<0.001)					
Colorectal	10.88	6.86	8.00	3.00	30.00
Gynecological	6.23	3.96	5.00	2.00	15.00
Trauma	6.71	2.93	6.00	3.00	12.00
Upper GI	9.75	4.74	8.50	6.00	20.00
Previous surgery setting (P=0.120)					
Emergency	9.03	6.32	7.50	2.00	29.00
Elective	11.67	7.54	9.00	2.00	30.00
Previous surgery access (P=0.352)					
Open	10.79	6.92	9.00	2.00	30.00
Laparoscopic	7.50	4.04	6.50	4.00	13.00
Number of previous surgery (P=0.016)					
1	8.21	5.86	6.00	2.00	30.00
2	13.72	7.28	12.00	4.00	30.00
≥3	13.14	6.84	14.00	4.00	20.00
Previous peritonitis (P=0.531)					
Yes	9.35	4.32	9.00	3.00	18.00
No	10.23	7.57	8.00	2.00	30.00
Previous bowel obstruction (P=0.302)					
Yes	11.68	7.01	11.00	3.00	29.00
No	9.79	6.84	8.00	2.00	30.00
ASA score (P=0.150)					
I	9.17	5.66	7.00	2.00	22.00
II	8.39	5.74	6.00	2.00	20.00
III	12.35	8.74	9.00	3.00	30.00
IV	12.20	5.59	12.00	6.00	20.00
Bowel resection (P=0.058)					
Yes	12.72	9.72	9.00	0.00	30.00
No	9.57	8.76	6.00	0.00	30.00
Necrotic bowel (P=0.653)					
Yes	10.64	7.22	8.00	2.00	30.00
No	9.79	6.82	8.00	2.00	30.00
Postoperative complications (P=0.285)					
Yes	11.45	6.90	9.50	3.00	30.00
No	9.59	6.81	8.00	2.00	30.00
Perioperative death (P=0.648)					
Yes	10.27	8.65	7.50	3.00	30.00
No	11.32	9.14	9.00	0.00	30.00
Early reintervention (P=0.083)					
Yes	16.26	11.42	16.00	3.00	30.00
No	10.64	8.34	8.00	0.00	30.00
Early bowel re-obstruction (P=0.075)					
Yes	19.16	12.23	21.00	3.00	30.00
No	7.91	7.25	4.00	1.00	29.00
Operative duration (min) (P<0.001)					
PAI 0-5	73.70	46.02	60.00	20.00	300.00
PAI 6-10	113.12	76.58	90.00	25.00	370.00
PAI 11-15	103.33	48.83	95.00	32.00	240.00
PAI 16-20	133.66	70.39	119.50	55.00	300.00
PAI 21-25	104.37	53.34	90.00	60.00	195.00
PAI 26-30	165.20	74.43	140.00	69.00	345.00

PAI, Peritoneal Adhesions Index; ASA, American Society of Anaesthesiologists score; Upper GI, upper gastro intestinal; min, minutes.

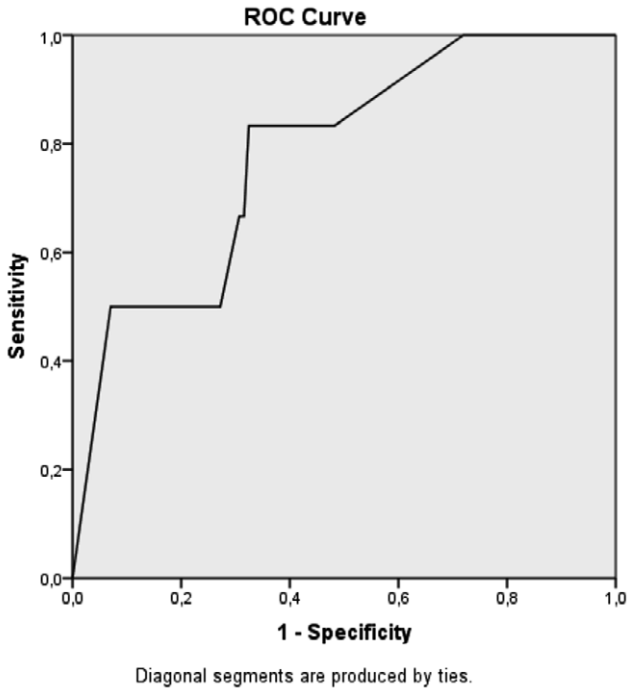


Figure 5. ROC curve studying relationship between PAI score and early bowel re-obstruction (AUC=0.8).

their re-formation. Several studies on this topic were conducted. However, up to now, the lacking of a standardized method of measure, for adhesions severity, could have partly compromised their reliability.

Conclusions

PAI is a reliable score and a valid tool to obtain a standardized and comparable definition of intra-abdominal adhesions. It is also useful for predicting intraoperative findings and postoperative outcomes.

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