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Predictive value of procalcitonin for intestinal ischemia and/or necrosis in pediatric patients with adhesive small bowel obstruction (ASBO)

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ABSTRACT

Purpose: Evaluate serum procalcitonin (PCT) level as a predictor of intestinal ischemia or necrosis (IN) in patients with postoperative adhesive small bowel obstruction (ASBO).
Methods: Prospective cohort of consecutive patients with ASBO. Patients previously treated with antibiotics or septic were excluded. PCT was measured at the diagnosis of ASBO and every 24 h afterwards. Main outcome: intestinal ischemia or necrosis (IN).
Results: Fifty-nine patients were included, 12 of whom were excluded; 47 patients remained in the study; male-to-female ratio = 1.9:1. Management: medical in 15 cases (32%) and surgical in 32 (68%). Main outcome: Intestinal necrosis (IN) in 10 patients (21.3%). Mean PCT level was higher in patients with IN (15.11 ng/ml vs. 0.183 ng/ml, p = 0.002), the proportion of patients with elevated PCT (>0.5 ng/dl) was higher in patients with IN (70% vs. 8.1%, p = <0.001, RR = 26.4 with a 95% CI of 4.39–159.5). Elevated PCT levels at diagnosis had a 70% positive predictive value (PPV) and 91.8% negative predictive value (NPV) for prediction of IN. With a PCT value at diagnosis of >1.0 ng/dl, PPV was 87.5% and NPV, 92.3%.
Conclusions: PCT levels are closely related to the presence of intestinal ischemia and necrosis in children with ASBO.
Level of evidence: Study of Diagnostic Test, Level II.

Intestinal obstruction is a frequent cause of hospitalization and the most common etiology is postoperative adhesions [1]. Acute small bowel obstruction secondary to postoperative adhesions (ASBO) occurs in around 1% to 6% of pediatric patients who undergo abdominal surgery [2,3], and when it happens, the risk of intestinal ischemia and necrosis is approximately 20%. These ischemia and necrosis can in turn cause perforation and peritonitis, thus compromising patients' lives [4]. Consequently, it is of the utmost importance to promptly identify intestinal ischemia and/or necrosis so that adequate treatment may be implemented. Though initially all ASBO cases are medically treated with fasting, intravenous (IV) fluids and gastric decompression, the decision for surgical management is made when there is persistent obstruction for 48 to 72 h despite medical treatment or before, when there is suspicion of intestinal ischemia or necrosis (IN). At the moment, there is no specific marker, whether clinical, biochemical nor imaging, capable of detecting the presence of IN in these patients.

Procalcitonin (PCT) is a 116-amino-acid precursor protein of calcitonin [5,6] secreted by thyroid C cells. In normal physiological conditions, serum levels are very low (<0.1 ng/ml) and it increases in case of infection or sepsis [7]. In 2005, the first report of the association of elevated PCT levels and intestinal ischemia was published [8] and since then there have been three other publications in adult patients where this finding has been corroborated [5,9,10]. With this shortage of information, we believe that there is need for more evidence to corroborate that PCT really increases in pediatric patients with IN secondary to postoperative adhesive small bowel obstruction.

Abbreviations: ASBO, Acute Small Bowel Obstruction; IN, Ischemia or necrosis; PCT, Procalcitonin.

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The purpose of this study is to evaluate serum elevation of PCT as a predictor of IN in pediatric patients with postoperative adhesive small bowel obstruction; this will contribute to expand the evidence on the association of this protein to IN, in addition to being the first report of results in pediatric population.

1. Material and methods

A single center prospective clinical study was conducted with a cohort of consecutive patients with ASBO and successive measurements PCT were obtained.

1.1. Population

All patients between ages 0 and 18 years with diagnosis of ASBO who were managed at a tertiary level of care hospital between February 2015 and January 2016 were included in the study. Diagnostic criteria for inclusion of patients were a clinical course of intestinal obstruction (bilious emesis, abdominal distention, and lack of bowel movements through the rectum) as demonstrated with vertical abdominal x-rays that showed air–fluid levels and absence of gas below the obstruction, as well as a history of previous abdominal surgery. Patients who were excluded from the study included: those who had received antibiotic therapy in the days prior to the diagnosis of ASBO, since their PCT levels would not be elevated as expected; [11] patients with sepsis or septic shock, as their condition was associated with increased PCT levels, [12,13] and patients whose parents didn't authorize their participation. Patients who were included in the study were initially managed with fasting, IV fluids and gastric decompression, and blood samples were taken to measure their serum PCT level at the time of ASBO diagnosis, as well as every 24 h until remission of the obstructive condition (patient tolerating oral diet) or until patient was taken to surgery. The decision to operate the patients was based on one or more of the following reasons: intense abdominal pain, persistent lactatemia, persistent leukocytosis or failure of medical treatment when, despite fasting and nasogastric tube for 72 h, the patient failed to pass stools or gas, with persistence of air fluid levels on the x-ray.

1.2. Measurement of serum levels of PCT

Two ml of blood was obtained for every PCT measurement in a heparin-containing tube that was subject to centrifugation to allow the use of serum. PCT levels were measured using the quantitative CLIA assay (LIAISON® Brahms PCT® II GEN) provided by DICIPA® Laboratories. PCT normal reference value is <0.5 ng/dl, so any level above this number was considered elevated.

The decision to whether continue medical treatment in these patients or perform surgery was made by the team of pediatric surgeons and was based on the patient's clinical evolution and laboratory test and/or imaging data. The group was blinded regarding to the PCT serum levels.

1.3. Main outcome

Presence or absence of intestinal ischemia or necrosis (IN).

1.3.1. Evaluation of outcome

When the patient was operated, the presence of IN was assessed by the color of the bowel, peristalsis and mesenteric vessel pulses during laparotomy or adhesiolysis. In cases of intestinal ischemia, the bowel was again assessed upon correction of the causal factor (adhesions, internal hernia or volvulus) with the application of warm dressings, and if recovery was observed, the wound was closed; otherwise, a resection and anastomosis or intestinal stoma was performed and the surgical specimen was sent for histopathology analysis. All patients who received successful medical treatment and were discharged, were classified as without IN.

2. Plan of analysis

Mean PCT levels were compared between patients who had IN and the rest of the patients, in patients who underwent surgery PCT levels were compared in those with IN versus those without IN. Finally, PCT levels were compared between those patients who received medical treatment and those with surgical intervention.

For the comparison of mean serum PCT levels, we used Student's t test and the X2 or Fisher's exact test was used to compare proportions. When significance was observed ($p < 0.05$), relative risk (RR) and its 95% confidence interval (CI) were estimated. Additionally, we evaluate PCT sensitivity, specificity, positive and negative predictive values for IN at different cutoff points. The Statistical Package for the Social Sciences v 18.0 (SPSS) statistical program was used.

3. Results

Fifty-nine patients were included in the study; one of them was excluded because the patient was not interested in participating and 11 more were excluded for other reasons: 5 had sepsis or septic shock and 6 had been previously treated with antibiotics. The final sample included 47 patients. There was a predominance of male patients (66%), with a male-to-female ratio of 1.9:1, and an age ranging between 0 to 17 years, with a median of 4 years old. The distribution per age group was: 2 newborns, 10 infants, 18 preschools, 6 children, and 11 adolescents. Twenty-seven patients (57.4%) had symptoms for fewer than 24 h and 20 (42.6%) had symptoms for more than 24 h ($p = NS$).

When analyzing the type of surgery performed prior to the occurrence of ASBO, we observed that there was a predominance of adhesiolysis, intestinal resection and stoma creation/closure.

Regarding the treatments prescribed for the occurring ASBO, 15 patients (32%) were successfully managed with medical treatment and 32 (68%) required surgery. Of the 32 patients managed surgically, 10 (21.3%) had intestinal ischemia or necrosis documented, and the remaining 22 patients did not have IN. When adding the 15 patients who received medical treatment, the final number of patients without IN was 37 (78.7%).

Two of the 10 patients with IN who underwent surgery had intestinal recovery during surgery, while eight required intestinal resection; in all eight resected specimens, histopathology analysis reported transmural ischemic enteritis and/or extensive necrosis.

Regarding PCT levels at the time of ASBO diagnosis we found that 37 patients had normal values (78.7%) and levels were elevated in 10 patients (21.3%). There was no correlation between elevated levels and age, nor within duration of symptoms ($p = NS$) (Table 1). As several patients had either successful medical treatment or failure to it before 72 h, measurement of PCT was as follows: 47 patients (100%) had PCT measured at diagnosis, 27 patients (57.4%) had PCT measured at 24 h of diagnosis, 12 (25.3%) at 48 h and only 6 (12.7%) at 72 h. Of the 37 patients with normal PCT at the time of diagnosis, 34 (91.9%) ended up not having IN at final evaluation while 3 (8.1%) did (Fig. 1). It is worth noting that, compared to their PCT levels at the time of diagnosis, 2 of the 37 patients showed an increase in their PCT levels at the 24 h-measurement, and 1 of them did have IN. Of the 10 patients who had elevated PCT levels at the time of diagnosis, 7 (70%) did have IN and 3 (30%) did not.

Comparing the mean PCT levels at the time of diagnosis in the 47 patients in the study, we observed that the level was significantly higher in those patients who did have IN in contrast to those who did not (15.11 ng/ml vs. 0.183 ng/ml respectively, $p = 0.002$). If we only consider the 32 patients with surgical management, PCT levels in patients with IN were significantly higher in contrast to those who didn't have IN (15.11 ng/ml vs. 0.22 ng/ml respectively, $p = 0.002$). Lastly, when

Table 1
Epidemiological data, PCT levels and final condition of the intestine.

PATIENT #	AGE (YEARS)	SYMPTOMS DURATION	PCT AT DIAGNOSIS	PCT 24 h	PCT 48 h	PCT 72 h	TREATMENT	ISCHEMIA	NECROSIS
1	2	2	<0.10				S		
2	14	2	<0.10	0.2			S		
3	8	1	<0.10	<0.10			S		
4	2	2	0.15				S	YES	
5	7	2	11.84				S	YES	YES
6	9	1	<0.10				S		
7	15	2	<0.10	<0.10	<0.10		S		
8	0	1	<0.10	<0.10	<0.10	<0.10	MED		
9	3	2	<0.10				S		
10	1	1	<0.10				S		
11	4	2	<0.10	<0.10			MED		
12	1	2	0.38	0.56			S		
13	5	1	<0.10				S	YES	
14	0*	1	<0.10	<0.10	<0.10	<0.10	MED		
15	0*	1	19.7				S	YES	YES
16	7	1	<0.10				S		
17	0	2	2.05	1.85			S		
18	17	1	<0.10	<0.10			S		
19	4	1	0.54	0.87	0.78		MED		
20	7	1	<0.10	<0.10	<0.10		MED		
21	16	1	<0.10				S		
22	0	1	0.84	0.9			S		
23	5	2	<0.10				S		
24	1	1	<0.10				S		
25	3	2	6.83				S	YES	
26	5	1	12.3				S	YES	YES
27	3	2	<0.10	<0.10	<0.10		MED		
28	3	2	<0.10	<0.10	<0.10	<0.10	MED		
29	2	2	<0.10	<0.10			MED		
30	9	2	4.18				S	YES	YES
31	14	2	<0.10				S		
32	5	2	95.17				S	YES	YES
33	15	1	<0.10	<0.10			MED		
34	14	2	<0.10	<0.10	<0.10		S		
35	15	1	<0.10	<0.10			MED		
36	3	1	<0.10	<0.10	<0.10		S		
37	0	1	0.52				S	YES	
38	0	2	<0.10				S		
39	1	1	<0.10	<0.10	<0.10	<0.10	MED		
40	5	2	0.38	1.44			S	YES	YES
41	4	1	<0.10	<0.10			S		
42	3	1	<0.10	<0.10	<0.10	<0.10	MED		
43	13	1	<0.10				S		
44	15	1	<0.10	<0.10			MED		
45	0	1	<0.10	<0.10	<0.10	<0.10	MED		
46	14	1	<0.10	<0.10			S		
47	3	1	<0.10	<0.10			MED		

Age: *Patients 14 and 15 are newborns. Duration of symptoms: 1 = less than 24 h, 2 = more than 24 h. PCT levels are in ng/ml. Treatment: S = Surgical, MED = Medical.

correlating PCT levels in the surgical treatment group versus the group who received medical treatment, there was some difference but it was not statistically significant (4.879 ng/ml vs. 0.120 ng/ml, respectively, $p = 0.289$).

Besides PCT levels, when we compared the proportions of patients, we found that there was a higher proportion of patients with elevated PCT in the IN group in contrast to the group who did not have IN (70% vs. 8.1% respectively, $p = <0.001$ RR = 26.4 with a 95% CI: 4.39–159.5).

Finally, at the time of diagnosis, elevation of PCT levels (>0.5 ng/ml) showed a 70% positive predictive value (PPV) and 91.8% negative predictive value (NPV) for diagnosing IN. Furthermore, when we consider a PCT level > 1.0 ng/ml as positive at the time of diagnosis, the positive predictive value obtained was 87.5%, with a negative predictive value of 92.3%. We did not find a relationship between ages or the duration of symptoms for the outliers relative to PCT levels but, as we mentioned, we did have one patient with a normal level at diagnosis that increased the PCT level at 24 h and finally had IN (Table 1).

4. Discussion

Our results show that both, the level of PCT and the proportion of patients with elevated PCT at the time of ASBO diagnosis are significantly higher among patients with IN secondary to ASBO.

The decision to whether operate on patients with ASBO is complicated; ideally, it is desirable to operate on patients who will not improve with medical management but before irreversible intestinal ischemia, necrosis or perforation occurs. However, applying a universal surgical decision on all patients with postoperative adhesive small bowel obstruction will increase the number of unnecessary surgeries. Additionally, we need to bear in mind the risk of surgery on patients, such as accidental perforation or causing more adhesions, among others [14,15]. There are no specific markers capable of early detecting the presence of intestinal ischemia or necrosis [9]; hence, the decision to perform surgery during the medical treatment is based on the presence of intense abdominal or localized pain, fever, leukocytosis, lactic acidosis, increased C reactive protein (CRP), creatine phosphokinase (CPK) or gastric tube output, as well as on radiographic findings [1,16–19].

At our hospital, pediatric surgery residents oversee emergency patients during evening and night shifts. Furthermore, being a teaching center, we tell the residents that if they find leukocytosis, lactatemia, or intense abdominal pain they must proceed to operate on the patient. That is probably why 68% of the patients in this series were operated on—a higher ratio than in other series. Another contributing factor is the high ratio of patients that came to the Emergency Room with

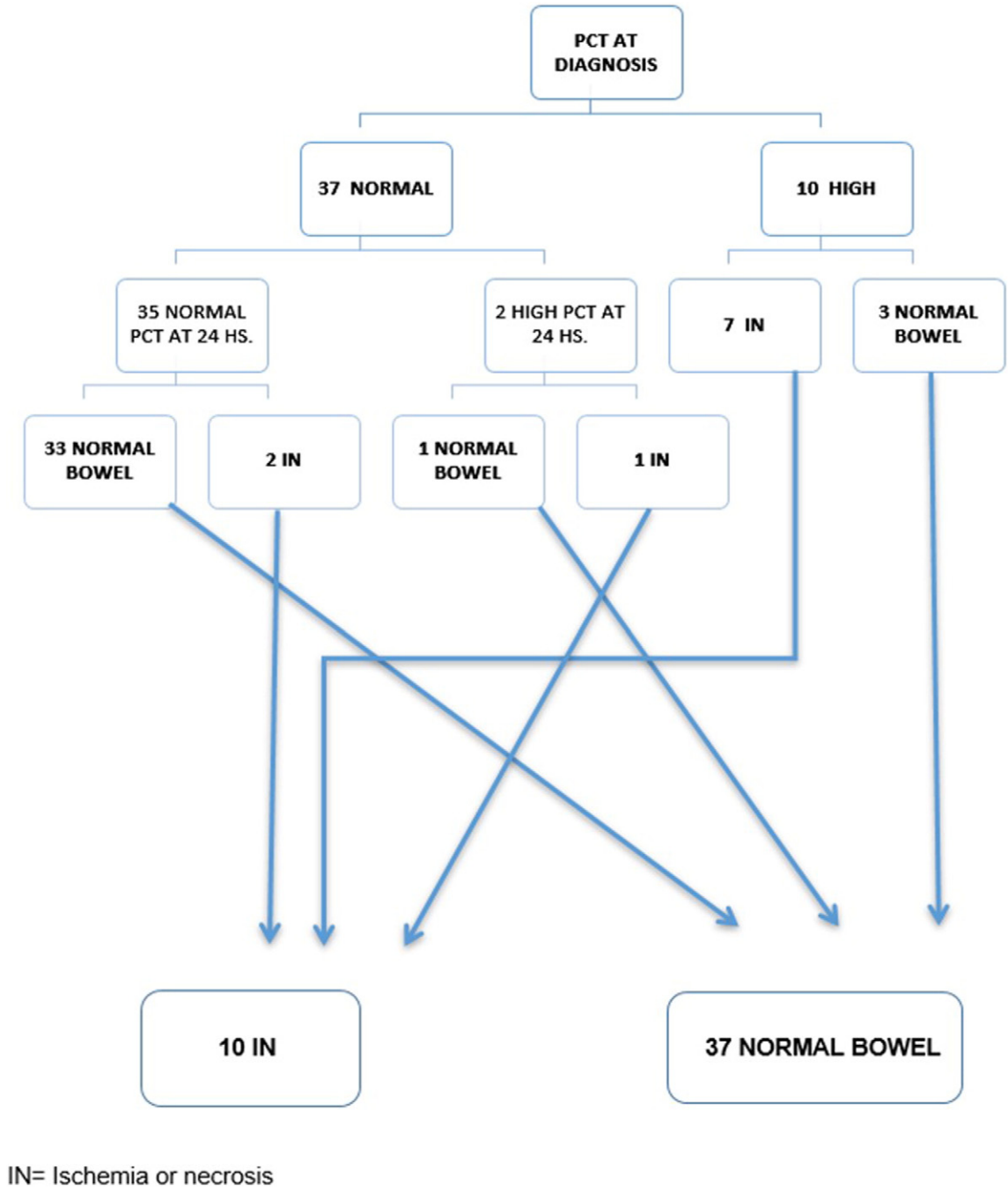

Fig. 1. Distribution of patients per PCT level at ASBO diagnosis, and final condition of the bowel.

more than 24 h of symptoms, which is a prognostic factor associated with medical treatment failure. Procalcitonin is a protein that is frequently elevated in sepsis [8,12,20] and is currently considered as a systemic marker of inflammatory response secondary to infection [11,13,21–24]. Elevations of PCT have been reported in pancreatitis [25], medullary thyroid cancer [6,7], lung small cell cancer [6], and others. Animal experimental models have also reported PCT elevation with acute mesenteric ischemia secondary to ligature of the mesenteric artery [27], a situation difficult to observe in children with adhesion-related intestinal obstructions; yet, it opens a window for research in the pediatric population with intestinal volvulus or in those cases of acute obstruction of the superior mesenteric artery.

Regarding PCT and its association to intestinal ischemia, animal models have shown the relation between PCT levels and IN [8,26]. To our knowledge there have been only other three studies in humans performed, one of them by Markogiannakis [9] who found an elevation of PCT as predictive of intestinal ischemia, particularly with levels greater than 1 ng/ml, which is consistent with our results where PCT predictive value is higher when a level greater than 1 ng/ml of PCT is considered. The other two reports are from Cosse et al. In the first one, they found that PCT levels were higher in the group of patients with ASBO who required surgical treatment compared to patients who were managed conservatively [5]. These results are like ours, though perhaps owing to the small sample size we were not able to obtain a statically significant difference despite the proportion of patients with elevated PCT, which was 4 times fold in the group of patients who required surgery. Both studies, Cosse's group and ours, showed an elevated PCT in patients with intestinal ischemia or necrosis. In the latest report by Cosse et al., they found that measuring PCT levels at different intervals (every 6 h) may help predict whether patients will need

surgery; they found that the predictive cutoff points for surgical treatment where at admission to the hospital (0.165 ng/ml), at 18 h after admission (with a level > 0.275 ng/ml) and at 24 h after admission (with a level > 0.255 ng/ml) [10]. In our study, we took PCT levels at the time of hospital admission and then every 24 h and found that if we consider not only the PCT level at the time of diagnosis, but also subsequent levels, the sensitivity and positive predictive value to identify ischemia or necrosis in children who had the diagnosis of ASBO increased. Although confidence intervals were quite broad because of such a small sample size, we can assert that a PCT level of >0.5 ng/ml at the time of ASBO diagnosis is associated with higher risk of IN in comparison with those patients whose PCT levels were normal. Because of this study, we changed our attitude toward a patient with ASBO; when the patient has a PCT level > 1.0 ng/ml we proceed to operate; if level is between 0.5 and 1.0 we keep evaluating closely with clinical criteria.

The strengths of our study are the following: the prevalence of IN in our sample was like that reported in these type of patients; hence, the predictive values are accurate; having blinded surgeons to PCT levels, which reduces bias, and lastly, the diagnosis of ischemia and necrosis by the surgeons was very precise, since there was a histopathology correlation in all the cases in whom the intestine was resected owing to IN. The weaknesses of our study are the small sample size and being a tertiary level hospital can influence the type of patient and the diagnosis of ASBO in emergency room.

It is worth mentioning that at diagnosis we had three patients with normal PCT levels (<0.5 ng/ml) and who also ended up with IN (false negatives). One of them increased its PCT level > 1.0 ng/ml after 24 h of diagnosis and had IN, so taking the PCT level at diagnosis and 24 h after would reduce the false negatives to two patients. With respect to the false positives, we had 3 patients with levels >0.5 ng/ml at diagnosis who did not end up having IN. Analyzing those patients, it is worth noting that only one of them had its level above 1.0 ng/ml. It appears that taking PCT levels greater than 1 ng/ml as positive, as well as obtaining measurements of PCT at the time of diagnosis and after 24 h, increases the predictive values for IN.

Hence, we need to increase the sample size to determine the proportion of false results and be able to study their possible causes. However, it's interesting to mention that all patients who ended up with intestinal necrosis secondary to ASBO had elevation of PCT greater than 1 ng/ml in the last measurement prior to surgery, which needs to be corroborated with further studies.

5. Conclusion

PCT is closely associated to the presence of intestinal ischemia and necrosis in children with postoperative adhesive small bowel obstruction, which makes it a good tool to timely suspect IN in patients with ASBO. The predictive values of PCT for predicting IN are high and even higher when PCT levels >1.0 ng/ml are considered.

An elevated PCT at the time of ASBO diagnosis has a 26-fold higher risk for ischemia or necrosis compared to patients with normal levels.

More studies are needed in the pediatric population to find the PCT level threshold with which greater sensitivity and positive predictive value for IN may be obtained and to determine the ideal time for the measurement of its level in patients with postoperative adhesive small bowel obstruction.

Conflicts of interest

None.

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