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Original Contribution

# Management of children presenting with low back pain to emergency department.

Francesco Saverio Biagiarelli, MD [a,1], Simone Piga, MSc [b], Antonino Reale, MD [c], Pasquale Parisi, MD, PhD [d], Marta Luisa Ciofi degli Atti, MD [b], Angelo Gabriele Aulisa, MD [e], Paolo Schingo, MD [f], Chiara Ossella, MD [c], Maria Pia Villa, MD [d], Umberto Raucci, MD, PhD [c,*,1]

[a] Department of Pediatrics, Bambino Gesù Children's Hospital, IRCCS, Roma, Italy
[b] Clinical Epidemiology, Bambino Gesù Children's Hospital, IRCCS, Rome, Italy
[c] Pediatric Emergency Department, Bambino Gesù Children's Hospital, IRCCS, Rome, Italy
[d] Chair of Pediatrics, NESMOS Department, Faculty of Medicine and Psychology, Sapienza University, Sant'Andrea Hospital, Rome, Italy
[e] Orthopaedics and Traumatology Division, Bambino Gesù Children's Hospital, IRCCS, Rome, Italy
[f] Department of Radiology, Bambino Gesù Children Hospital, IRCCS, Rome, Italy

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ABSTRACT

*Objective:* We aimed to describe characteristics, etiology and health care use in children with low back pain (LBP) presenting to pediatric emergency department (ED) and to develop an algorithm to design a diagnostic approach.

*Methods:* We conducted a 7-year cohort study of children admitted to ED with a primary complaint of LBP. They were classified into diagnostic groups: visceral LBP; traumatic LBP; non-visceral/non-traumatic LBP. To identify high-risk factors (red flags) associated with severe prognosis conditions (SPCs), we analyzed the non-visceral/non-traumatic group comparing the SPC children with those children without SPCs.

*Results:* Our population comprised 140 females (52.6%) and 126 males (47.4%), with a median age of 10.5 years. Eighty children (30.3%) were hospitalized, with an average length of stay of 8.53 ± 9.84 days. SPCs accounted for 28 patients (18.9%) of overall 148 with non-traumatic/non-visceral LBP. In this group, SPCs presented with earlier onset and longer duration of symptoms than non-SPCs. The presence of red flags was more significant in the SPCs group, 28 vs 18; 100% vs 15% ($p < 0.001$); sensitivity 100%, specificity 85%. Among SPCs, 78.6% were hospitalized vs non-SPC (16.8%) ($p < 0.001$); within SPC group 2 patients returned because of onset of red flags.

*Conclusion:* Our study identified significative high-risk factors (red flags) associated with serious outcomes (SPC group) compared to the non-SPC group, thereby ensuring specific treatment. We developed an algorithm based on previous literature and the findings of our study, which will need to be validated by future prospective research.



## 1. Introduction

Back pain in young people is more common than previously thought: the one-year prevalence rate varies between 7% and 58% [1-3]. The lifetime prevalence may be as high as 70–80% by age 20 years [4]; particularly lifetime prevalence rises from 11.6% at age 11 years to 50.4% at age 15 years [5]. Most of the studies on back pain in children were conducted in primary care or subspecialty practices or services and very few data exists describing epidemiology and etiology of pediatric patients presenting to the adult [6], and pediatric emergency departments (ED) [7,8].

Low back pain (LBP), defined as "pain limited to the region between the lower margins of the 12th rib and the gluteal folds" [9], is the most common type of back pain, occurring in about 60–80% of people at some point in their lives [10]. Some studies reported that the prevalence between schoolchildren, especially teenagers, is approximately 33% [11,12]. Some etiological predictors of highest risk of persistent LBP in teenagers are described [13,14]. It has been reported that those with LBP in childhood are at higher risk of LBP in adulthood [15]. To date, only clinical decision adult guidelines for LBP have been developed [16-20]. The etiology of LBP in pediatrics differs significantly from that in adults. Pediatric dogma suggests that children with back pain may

* Corresponding author.
*E-mail addresses:* fsaverio.biagiarelli@opbg.net (F.S. Biagiarelli), simone.piga@opbg.net (S. Piga), antonino.reale@opbg.net (A. Reale), pasquale.parisi@uniroma1.it (P. Parisi), marta.ciofidegliatti@opbg.net (M.L. Ciofi degli Atti), agabriele.aulisa@opbg.net (A.G. Aulisa), pmsalvatore.schingo@opbg.net (P. Schingo), chiara.ossella@opbg.net (C. Ossella), mariapia.villa@uniroma1.it (M.P. Villa), umberto.raucci@opbg.net (U. Raucci).
[1] Equally contributed to the work.

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have serious pathology, including malignancy and infection [21]. However, most causes of LBP in children are benign and self-limiting [22,23]. Nonetheless, serious illnesses must not be missed and only 12% to 26% of pediatric patients with LPB have a diagnosable cause [24-26]. The differential diagnosis includes trauma, infection, rheumatological disease, malignancy, musculoskeletal conditions and non-organic causes. Evaluation and management is challenging and distressing in pediatrics, especially in the emergency setting, also because of children's difficulties in describing experienced symptoms. The physician must be skilled in rapidly identifying the minor percentage of patients with organic conditions requiring further diagnostic procedures. This concern has led many children to undergo extensive and often unnecessary investigations, resulting in an increase in radiation exposure, patient/family anxiety and cost. Furthermore, it is essential to perform the most appropriate investigations to exclude serious underlying LBP. Laboratory and imaging investigations should be targeted towards those with “red flag” symptoms and signs [21]. The recognition of red flags is essential for differential diagnosis and proper treatment since their presence increases the risk of underlying disease.

At present, no conclusive data is present in pediatric population on the presentation and management of LBP in the ED. The previous studies were based on patients assessed in specialty departments or referred to the ED specifically for back pain [6-8]. No studies shed light on signs or symptoms capable of identifying patients with severe prognostic conditions (SPCs).

Our study analyzed 7 years of retrospective data from the ED of a tertiary pediatric hospital, to assess the etiology and management of LBP in pediatrics. Specifically, the study aimed to describe general characteristics, etiology and health care utilization in the pediatric population with LBP trying to identify a correct diagnostic approach, and possible recognition of specific clinical pictures with correlated “red flags” associated with SPCs. Finally, we propose an algorithm with the purpose of helping ED physicians to evaluate and undertake a correct diagnostic approach in children with LBP.

## 2. Material and methods

After obtaining approval from the institutional ethic committee, we conducted a retrospective cohort study of patients, aged up to 18 years old, presenting to the ED of the Bambino Gesù Children's Hospital between January 2009 and December 2015 with a primary complaint of LBP. There is an ongoing scientific collaboration between the ED of our tertiary hospital and the Post-graduate School in Pediatrics of the Faculty of Medicine and Psychology. All patients enrolled in the study presented LBP with diagnosis made in the ED; patients previously diagnosed were excluded.

The following data was extracted from each medical record: age, gender, triage code, time of onset divided into three categories according to the duration of signs/symptoms before admission, history, physical examination findings, associated or comorbid conditions, specialist consultations, imaging techniques such as computed tomography (CT) scan and magnetic resonance imaging (MRI), final diagnosis, hospital admission and length of stay, as applicable.

The following color codes were used to describe the clinical conditions at the time of triage: red or immediate (need to be seen immediately); yellow or very urgent, with high priority (need to be seen in <15 min), green or urgent (need to be seen in 60–120 min), white or non-urgent (need to be seen after previous triage codes).

Patients were classified into diagnostic categories that were established before data collection. In particular, we divided our sample into the subsequent groups: visceral (pulmonary, renal and abdominal conditions); traumatic (subdivided into minor and major trauma); non-visceral/non-traumatic. After the subgroup division, on the basis of the final diagnosis, we analyzed specifically the non-visceral/non-traumatic LBP comparing the severe prognosis conditions (SPCs) (malignancy; infections; severe rheumatological, neurological and orthopedic diseases) with non-SPCs (see Fig. 1 for detail). Finally, we produced an algorithm, derived and modified from previous literature [27-29] in order to promptly identify all patients with SPCs.

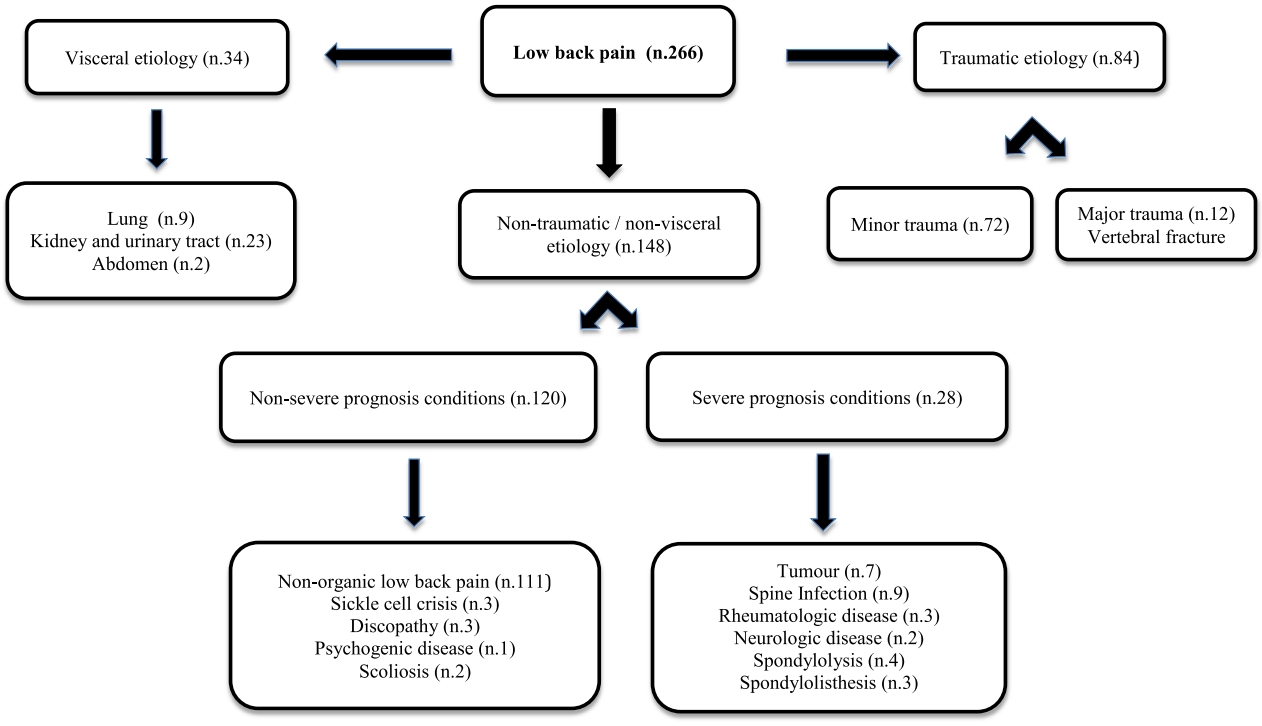


**Fig. 1.** Etiological group subdivision.

**Table 1**
Demographic and clinical characteristics of low back pain. Total sample N = 266.

| Characteristics | | n | (%) |
|---|---|---|---|
| Age in years | Median (IQR) | 10.31 | (1.4–3.3) |
| | Mean ± SD | 10.31 | (4.01) |
| Sex | Female | 140 | (52.6) |
| | Male | 126 | (47.4) |
| Clinical onset | Within 24 h | 71 | (26.7) |
| | 24–48 h | 81 | (30.4) |
| | 48–72 h | 43 | (16.2) |
| | Over 72 h | 71 | (26.7) |
| Triage | White | 13 | (4.9) |
| | Green | 225 | (84.6) |
| | Yellow | 28 | (10.5) |
| | Red | 0 | – |
| Underlying disease | Absent | 251 | (94.4) |
| | Present | 15 | (5.6) |
| Nighttime pain | Absent | 256 | (96.2) |
| | Present | 10 | (3.8) |
| Daytime pain | Absent | 161 | (60.5) |
| | Present | 105 | (39.5) |
| Onset | Spontaneous | 161 | (60.9) |
| | Sport | 5 | (1.9) |
| | Physical effort | 15 | (5.6) |
| | Trauma | 85 | (32) |
| Site of pain | Localized | 194 | (72.9) |
| | Widespread | 31 | (11.7) |
| | Irradiated | 41 | (15.4) |
| Low back pain | Absent | 30 | (11.3) |
| | Present | 236 | (88.7) |
| Fever | Absent | 239 | (89.8) |
| | Present | 27 | (10.2) |
| Gastrointestinal symptom | Absent | 254 | (95.5) |
| | Present | 12 | (4.5) |
| Weakness | Absent | 257 | (96.6) |
| | Present | 9 | (3.4) |
| Weight loss | Absent | 263 | (98.9) |
| | Present | 3 | (1.1) |
| Urinary symptom | Absent | 251 | (94.4) |
| | Present | 15 | (5.6) |
| Hypostenia | Absent | 262 | (98.5) |
| | Present | 4 | (1.5) |
| Gait disorders | Absent | 256 | (96.2) |
| | Present | 10 | (3.8) |
| Sensitive disorders | Absent | 260 | (97.7) |
| | Present | 6 | (2.3) |
| Hypotonia | Absent | 264 | (99.3) |
| | Present | 2 | (0.7) |
| Antalgic position | Absent | 246 | (92.5) |
| | Present | 20 | (7.5) |
| Scoliosis | Absent | 262 | (98.5) |
| | Present | 4 | (1.5) |
| Swelling | Absent | 259 | (97.4) |
| | Present | 7 | (2.6) |
| Ecchymotic lesion | Absent | 256 | (96.2) |
| | Present | 10 | (3.8) |
| Petechiae | Absent | 264 | (99.2) |
| | Present | 2 | (0.8) |
| Lymphadenopathy | Absent | 262 | (98.5) |
| | Present | 4 | (1.5) |
| Hepatosplenomegaly | Absent | 263 | (98.9) |
| | Present | 3 | (1.1) |
| Abdominal pain | Absent | 241 | (90.6) |
| | Present | 25 | (9.4) |
| Hematuria | Absent | 262 | (98.5) |
| | Present | 4 | (1.5) |
| Dysuria | Absent | 250 | (94) |
| | Present | 16 | (6) |
| Giordano sign | Absent | 238 | (89.5) |
| | Present | 28 | (10.5) |
| Blood samples | Absent | 208 | (78.2) |
| | Present | 28 | (21.8) |
| Ultrasound | Absent | 185 | (69.6) |
| | Present | 81 | (30.4) |
| X-ray | Absent | 126 | (47.4) |
| | Present | 140 | (52.6) |
| CT-MRI | Absent | 54 | (20.3) |
| | Present | 212 | (79.7) |
| Outcome | Discharged | 183 | (69.3) |
| | Hospitalized | 80 | (30.3) |
| | Refuse of hospitalization | 1 | (0.4) |

CT: computed tomography; MRI: magnetic resonance imaging.

### 2.1. Statistical analysis

We describe the clinical and demographic characteristics of all the patients enrolled in each subgroup (visceral, traumatic and non-traumatic/non-visceral), providing details of the non-traumatic/non-visceral group divided into SPC and non-SPC condition. The groups were compared by absolute and relative frequencies, median, IQR, and range, means and standard deviation were computed as appropriate. The Shapiro–Wilk test was applied to assess the normality of the distribution of each variable. Comparisons among groups were performed using the Chi-squared test or Fisher's exact test for categorical variables as appropriate. Medians were compared with the Wilcoxon or Mann-Whitney rank-sum test. We calculated descriptive statistics and report median with IQR and ranges or mean ± SDs as appropriate for the data distribution. We report percentages for categorical or dichotomous variables. We performed univariate analysis to determine the strength of association between the predictor variables and outcomes. We calculated sensitivity, specificity, positive and negative predictive values, prevalence, and 95% confidence interval for all variables (physical evaluation, blood tests and red flags such as nighttime pain, LBP persistence, fever, neurological signs or symptoms, and weight loss) in relation to the SPC vs non-SPC group. The sensitivity, specificity, predictive values and 95% confidence intervals was computed for at least the presence of one red flag. Statistical significance was assumed as $p < 0.05$ for all tests. All statistical analyses were performed using STATA, Statistical Software: Release 13. College Station, Tx: StataCorp 2013.

## 3. Results

### 3.1. Demographic data, clinical features and diagnostic approach in the whole sample

During the 7-year period of our study, of all children admitted to the ED of our tertiary pediatric hospital (360,769 patients), 266 subjects (7 per 10,000 admission to ED) presented LBP. Patient characteristics are described in Table 1. Our population comprised 140 females (52.6%) and 126 males (47.4%); (ratio M/F: 0.9). Children were aged from 1 to 17.9 years (median age 10.5 years, IQR 7.7–13.3; mean 10.3 ± 4.0). The clinical onset of LBP was in most cases >24 h (n = 195; 73.3%). At ED admission the triage code was mainly green or yellow. Fifteen patients reported comorbidities (5.6%). LBP was mostly spontaneous (n = 162; 60.9%), localized (n = 194; 72.9%) and isolated or combined with other symptoms on ED admission. Fortysix patients needed an orthopedic specialist consult (17.3%). Blood tests were performed in 58 patients (21.8%), X-ray in 151 patients (52.6%), CT/MRI in 54 patients (20.3%) and ultrasound scan in 81 patients (30.4%). 80 children with LBP (30.3%) were hospitalized, with an average length of stay of 8.53 ± 9.84 days (Table 1).

Distribution of the various etiologies for LBP is reported in Fig. 2.

### 3.2. Group subdivision

The 266 patients we separated into 3 main groups: a) Visceral (pulmonary, renal, abdominal conditions); b) Traumatic (minor and major trauma); c) Non-visceral/Non-traumatic conditions. Subsequently we

analyzed only the non-traumatic/non-visceral group which was divided into SPC and non-SPC group (Fig. 1).

### 3.3. Comparison between SPCs and non-SPCs in the non-traumatic/non-visceral group: clinical characteristics and diagnostic findings

Children with SPC etiologies accounted for 28 patients (18.9%) of overall 148 admitted to the ED for non-traumatic/non-visceral LBP, as reported in Table 2. The two groups are homogeneous by age (median age of both groups 11.6 years) and gender. SPCs were characterized by a longer onset and duration of symptoms than non-SPCs (median time of clinical onset was 7 days in the SPC group vs 3 days in the non-SPC group; $p = 0.003$). The presence of red flags was significantly more frequent in the SPC group, 28 vs 18 patients; 100% vs 15% ($p < 0.001$). The sensitivity of red flag presence was 100%, while specificity was 85% (see Table 3 for detail). Among SPCs, 22 patients (78.6%) were hospitalized vs 20 with non-SPCs (16.8%) ($p < 0.001$). The other 6 SPC patients were discharged from the ED with a follow-up visit in our hospital; in particular, 4 of them returned to the hospital a few days later for the planned visit, while 2 returned due to persistence of LBP and onset of red flags. The length of hospital stay was significantly longer in the SPC group compared to the non-SPC group (median 15 days vs 5, $p < 0.001$) (Table 2).

### 3.4. Diagnostic algorithm development

Considering the previous literature [27-29] and our cohort population study we developed an algorithm, actually in use in our ED (Fig. 3), that we propose for future studies in order to promptly identify all patients with SPCs. This algorithm takes into account mainly non-visceral/non-traumatic conditions.

## 4. Discussion

Unlike adults, where LBP is common and often due to non-specific causes, in children it may be the symptom of a serious condition [30]. A strong point in our study was the large population sample, thus providing reliable epidemiological data from the ED of a tertiary pediatric Italian hospital, showing an incidence of 7.3 per 10,000 admission. To date, there are few studies on patients presenting with back pain, both to the adult [6] and pediatric EDs [7,8]. Furthermore, no pediatric study has specifically evaluated only LBP in the emergency setting. We specifically investigated non-traumatic/non-visceral LBP in the intent of recognizing specific clinical pictures with correlated "red flags", trying to determine the reliability of a diagnostic pathway to identify patients with SPCs.

The etiology of LBP in adults differs from children, particularly for some categories such as vascular, oncologic, rheumatic and metabolic bone diseases [31]. Like other reported pediatric studies on back pain [7,8], LBP in our population sample, represented a multiple and variegated etiological spectrum (Fig. 1). Nevertheless, comparison with previous pediatric studies in similar emergency settings [7,8] is difficult because of the different clinical population, the inclusion and exclusion criteria, and the different subgroup etiological division. Our study identified risk factors associated with serious underlying diseases in pediatric patients with LBP due to non-traumatic/non-visceral conditions. In these cases primary assessment (complete family and personal history, physical examination) in combination with imaging and laboratory evaluation may be warranted to rule out systemic and/or organic causes [32]. Furthermore, we divided our patient sample, through history and physical evaluation, into 3 main groups (visceral, non-traumatic/non-visceral and traumatic LBP). We concentrated our attention on the non-traumatic/non visceral group, initially without a specific diagnosis, differentiating patients with SPCs and non-SPCs by identifying specific red flags associated with serious underlying conditions. In our non-traumatic/non visceral group the most frequent diagnosis among non-SPCs (75%) was non-specific (mechanical) LBP. Other causes were spinal disorders, such as scoliosis and disk herniation, hematological disorders such as sick cell disease and psychogenic causes. The SPCs (18.9%) presented malignancy, spine infections, rheumatological diseases, neurological and severe orthopedic disorders (Fig. 1). It is important to stress again that SPCs occur more frequently in children compared with adults [30]. Thus, ED physicians must be skilled to rapidly identify the few patients with potentially SPCs causing LBP. These patients require further diagnostic imaging evaluation of the lumbar spine, which should be performed only when needed since potentially

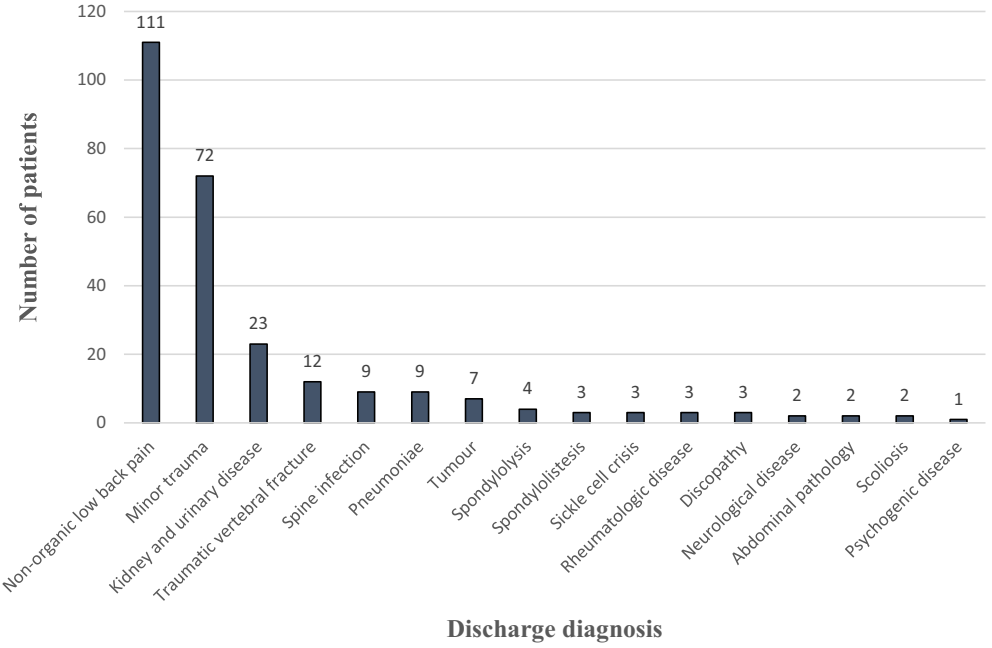


**Fig. 2.** Etiologies of low back pain.

**Table 2**
Clinical characteristics and diagnostic findings in non-traumatic/non visceral group (severe prognosis condition versus non-severe prognosis conditions).

| Non traumatic LBP | Severe prognosis conditions (SPC) | | Non-severe prognosis conditions (non-SPC) | | Total | | |
|---|---|---|---|---|---|---|---|
| | n. 28 | | n. 120 | | n. 148 | | |
| | n | (%) | n | (%) | n | (%) | p-Value |
| Sex | | | | | | | 0.066 |
| Female | 10 | (35.7) | 66 | (55.0) | 76 | (51.4) | |
| Male | 18 | (64.3) | 54 | (45.0) | 72 | (48.7) | |
| Age in years | | | | | | | 0.773 |
| Median (IQR) | 11.6 | (7.5–15.1) | 11.6 | (9.27–13.9) | 11.6 | (8.8–14.0) | |
| Triage | | | | | | | 0.098 |
| White | 0 | (−) | 13 | (10.8) | 13 | (8.9) | |
| Green | 24 | (85.7) | 98 | (81.7) | 122 | (82.4) | |
| Yellow | 4 | (14.3) | 9 | (7.5) | 13 | (8.8) | |
| Red | 0 | (−) | 0 | (−) | 0 | (−) | |
| Onset and duration of symptoms (days) | | | | | | | 0.003 |
| Median (IQR) | 7 | (4–15) | 3 | (1–7) | 3 | (1–7) | |
| Hospitalization | | | | | | | <0.001 |
| Absent | 6 | (21.4) | 100 | (83.3) | 106 | (71.6) | |
| Present | 22 | (78.6) | 20 | (16.7) | 42 | (28.4) | |
| Time of hospitalization (days) | | | | | | | <0.001 |
| Median (IQR) | 15 | (10–30) | 5 | (4–8) | 9 | (4–15) | |
| Presence of red flags | | | | | | | <0.001 |
| Absent | 0 | (−) | 102 | (85.0) | 102 | (68.9) | |
| Present | 28 | (100.0) | 18 | (15.0) | 46 | (31.1) | |
| Nighttime pain | | | | | | | <0.001 |
| Absent | 22 | (78.6) | 120 | (100.0) | 142 | (96.0) | |
| Present | 6 | (21.4) | 0 | (−) | 6 | (21.4) | |
| Weight loss | | | | | | | <0.001 |
| Absent | 24 | (85.7) | 120 | (100) | 144 | (97.3) | |
| Present | 4 | (14.3) | 0 | (−) | 4 | (2.7) | |
| Persistence of LBP | | | | | | | <0.001 |
| Absent | 4 | (14.3) | 114 | (95.0) | 118 | (79.7) | |
| Present | 24 | (85.7) | 6 | (5.0) | 30 | (20.3) | |
| Fever | | | | | | | <0.001 |
| Absent | 21 | (75) | 115 | (95.8) | 136 | (91.9) | |
| Present | 7 | (25) | 5 | (4.2) | 12 | (8.1) | |
| Neurological signs and symptoms | | | | | | | <0.001 |
| Absent | 16 | (57.1) | 119 | (99.2) | 135 | (91.2) | |
| Present | 12 | (42.9) | 1 | (0.8) | 13 | (8.8) | |
| Age < 4 years | | | | | | | 1.000 |
| Absent | 27 | (96.4) | 113 | (94.2) | 140 | (94.6) | |
| Present | 1 | (3.6) | 7 | (5.8) | 8 | (5.4) | |
| Altered physical evaluation | | | | | | | 0.002 |
| Absent | 1 | (3.6) | 38 | (31.7) | 39 | (26.4) | |
| Present | 27 | (96.4) | 82 | (68.3) | 109 | (73.7) | |
| Altered blood exams | | | | | | | <0.001 |
| Absent | 15 | (53.6) | 117 | (97.5) | 132 | (89.2) | |
| Present | 13 | (46.4) | 3 | (2.5) | 16 | (10.8) | |

LBP: low back pain.

hazardous for pediatric patients. In literature red flags reported are pain unresponsive to NSAIDs and rest; nighttime pain; weight loss; presence of neurological signs or symptoms (weakness, bowel or bladder dysfunction, radiculopathy) especially if progressive; age under 4 years old and fever. Clearly, the presence of red flags increases the chances to recognize underlying disease [8,21,27,28]. Laboratory and imaging investigations should be targeted towards those with "red flag" symptoms and signs without over investigating patients. In our sample, the majority of children did not have underlying SPCs (Figs. 1, 2). Evaluation of the patient's condition at the time of triage was important to differentiate children with high risk conditions, and there was significant difference regarding the time from the onset of the clinical picture to ED

**Table 3**
Sensitivity, specificity and predictive values in non-traumatic/non-visceral group, N.148.

| Characteristics | Sensitivity% | 95% CI | Specificity% | 95% CI | PPV% | 95% CI | NPV% | 95% CI |
|---|---|---|---|---|---|---|---|---|
| Presence of red flags | 100.0 | (100.0–100.0) | 85 | (79.3–90.8) | 60.9 | (53.0–68.7) | 100.0 | (100.0–100.0) |
| Nighttime pain | 21.4 | (14.8–28.0) | 100.0 | (100.0–100.0) | 100.0 | (100.0–100.0) | 84.5 | (78.790.3) |
| Weight loss | 14.3 | (8.7–19.9) | 100.0 | (100.0–100.0) | 100.0 | (100.0–100.) | 83.3 | (77.3–89.3) |
| Fever | 25.0 | (18.0–32.0) | 95.8 | (92.6–99.1) | 58.3 | (50.4–66.3) | 84.6 | (74.7–90.4) |
| Persistence of LBP | 85.7 | (80.1–91.4) | 95 | (91.5–98.5) | 80.0 | (73.6–86.4) | 96.6 | (93.7–99.5) |
| Neurological signs and symptoms | 42.9 | (34.9–50.8) | 99.2 | (97.7–100.6) | 92.3 | (88.0–96.6) | 88.2 | (82.9–93.4) |
| Age < 4 years | 3.6 | (0.6–6.6) | 94.2 | (90.4–97.9) | 12.5 | (7.2–17.8) | 80.7 | (74.4–87.1) |
| Altered physical evaluation | 96.4 | (93.4–99.4) | 31.7 | (24.2–39.2) | 24.8 | (17.8–31.7) | 97.4 | (94.9–100.0) |
| Altered blood tests | 46.4 | (38.4–54.5) | 97.5 | (95.0–100.0) | 81.3 | (75.0–87.5) | 88.6 | (83.5–93.8) |

CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value, LBP: low back pain.

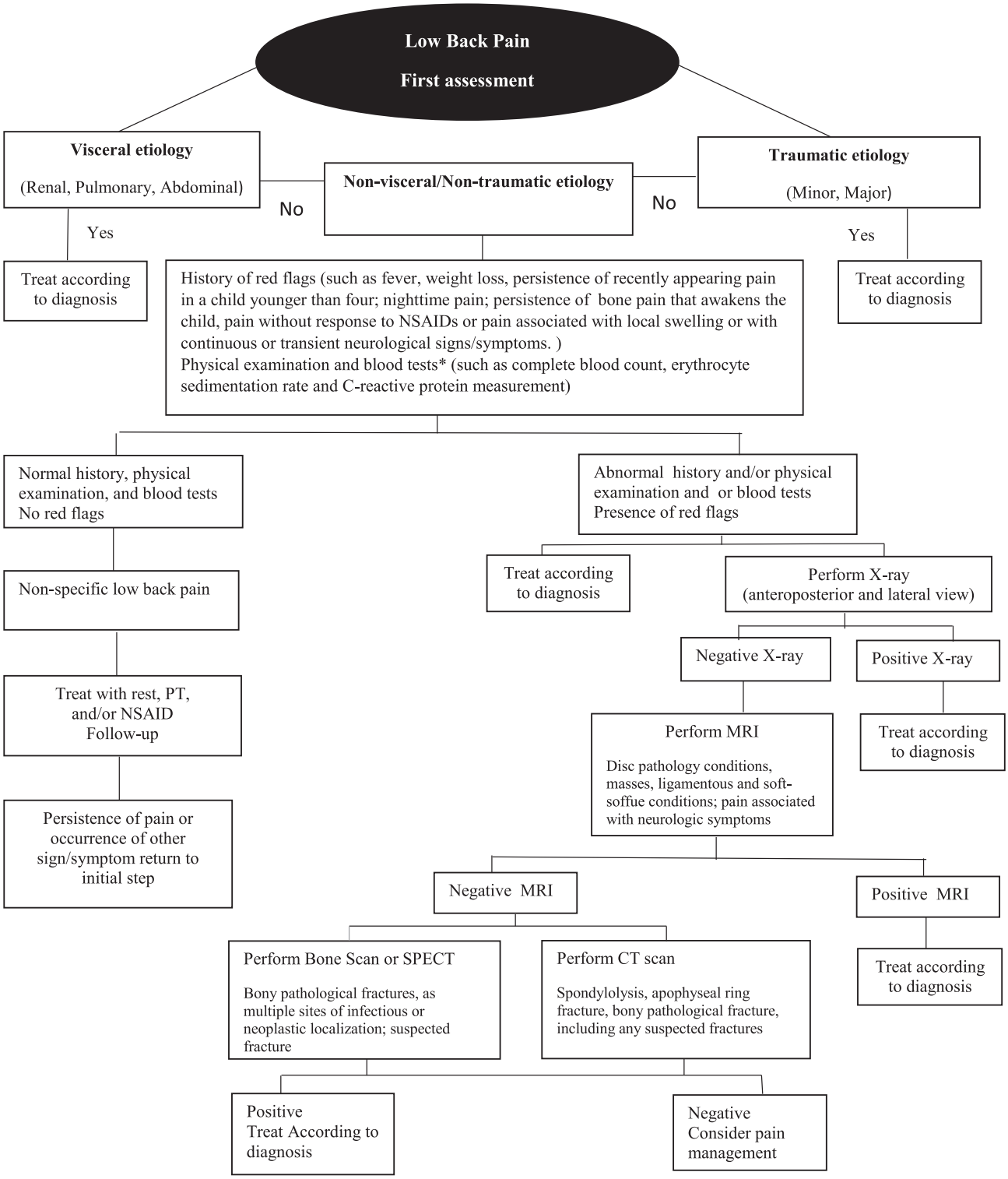


**Fig. 3.** Algorithm for evaluation of low back pain in pediatrics (*,**). *We perform blood test in all children with non-traumatic/non-visceral etiologies. **This approach can be applied also to back pain. PT: physical therapy, NSAIDs: nonsteroidal anti-inflammatory drugs. MRI: magnetic resonance imaging, CT: computed tomography, SPECT: single photon emission computed tomography.

admission. LBP was thought to be a rare complaint and frequently associated with organic conditions, especially SPCs, in children [3]. Instead during the last decades it has been demonstrated that LBP is more common than we thought; fortunately associated most of the time with non-specific/non-organic disorders with a peak of prevalence in adolescence [33]. Approximately 10% to 30% of the normal pediatric population can be expected to experience back pain by the time they reach their teens [34].

It is important to underline that LBP was never isolated in all children with SPCs, but associated with other signs or symptoms. Furthermore, our study demonstrated that the presence of red flags is an important predictor of serious outcomes. The presence of these red

flags comparing SPCs and non-SPCs is statistically significative (100% vs 15%; $p < 0.001$) with a high sensibility and specificity (100% and 85% respectively). We identified five major predictor variables (red flags) associated with serious outcome in LBP patients: nighttime pain, weight loss, persistent LBP non responsive to conservative treatment, fever and presence of neurological signs/symptoms (especially abnormal gait, sensitive disorders, weakness and bladder problems). All of these variables were statistically significant between the two groups and red flags were present in all SPCs patients. Obviously, sensitivity and specificity differed for each red flag. It would be interesting, from a clinical and prognostic point of view, in future studies to develop a clinical model to verify the importance of each red flag. Persistence of LBP was the red flag with highest specificity and sensibility (85% and 100%). Overall the presence of an abnormal physical exam was statistically different between the groups ($p = 0.002$) as well as altered blood tests ($p < 0.001$). Of the other signs and symptoms only the presence of lymphadenopathy or splenomegaly was statistically significant between groups ($p < 0.001$). Other significative differences were the rate of hospitalization ($p < 0.001$) and the length of hospitalization ($p < 0.001$) (Tables 2–3). On analyzing patients with isolated LBP (104 patients), we found that the majority of them were allocated in the non-SPCs group, 102 versus 2 patients; these 2 children returned because of onset of red flags at the second ED admission. For this reason follow-up management is very important in these patients to avoid any possibility of not diagnosing a serious condition. Age <4 years was not significant in our study but had a high specificity. It is important to stress that the presence of 1 or more red flags increases the risk and the probability of having an underlying disease. If associated with an abnormal physical exam and altered blood tests this risk increases exponentially. At present, in literature there are no pediatric guidelines for LBP and algorithms for childhood BP are rather scarce [27-29,35] (Fig. 3). On the basis of previous papers [27-29,35] and data deriving from our study, we elaborated a new algorithm in order to help physicians in the emergency setting (Fig. 3). The aim of the algorithm is to detect if all patients with SPCs, on the basis of presence of red flags, resulted in a correct diagnosis. Furthermore, only 2 of 28 patients with SPC were diagnosed on a second ED admission, due to the onset of red flags that they did not have the first time they presented to the ED (persistence of pain and/or onset of other new symptoms). This highlights the need for a follow-up strategy after the first ED examination to detect a small but important number of patients that have underlying serious conditions without red flags at the onset of LBP.

In children, the presence of isolated LBP may be easily correlated to benign conditions, especially if follow-up demonstrates non-LBP persistence. Regarding specialists' referral, we did not report a significative difference in the two analyzed groups, but clearly these data confirm the importance of a multidisciplinary approach also in emergency settings, especially for the diagnosis of certain diseases.

The use of CT scan and MRI of the spine was more significant in children with SPCs. We believe that our study warrants further prospective studies with an implementation program of our diagnostic algorithm to avoid useless and sometimes hazardous investigations in non-SPC patients. In addition, considering the large spectrum of LBP, if there are doubts about the diagnosis and warning signs are not present, other specialists, if available, should be consulted before opting for further unnecessary tests [36,37]. According to the data in literature, a growing use of diagnostic instruments such as X-ray or CT in the ED has been reported also in children, despite radiation risks [38,39]. This may reflect the increased need in physicians and patients for diagnostic certainty.

4.1 In addition to limitations due to a retrospective study design, the main limitation of our study is that the diagnostic work-up was based on the physician's judgement and not on a standardized protocol with related algorithm, now in use in our ED (Fig. 3).

## 5. Conclusions

LBP is not a rare ED problem in the pediatric population. A small but important number of patients have serious underlying conditions that should be suspected and detected at the first ED visit. The probability of having an organic disease is higher in the non-traumatic/non visceral group compared to the total sample. Our study has identified significative high-risk factors (red flags) associated with serious outcomes (SPC group) compared to the non-SPC group, thereby ensuring specific treatment. Such strides have yet to be made in pediatric literature, particularly within the setting of the pediatric ED. In fact, future large prospective multicentric studies in pediatric patients could be useful to validate our algorithm, to develop a strong clinical and diagnostic approach in order to identify all patients with serious underlying conditions. At the same time patients with benign conditions would be safely discharged home from the ED without unnecessary laboratory and imaging investigations, thereby improving patient care.

## Conflict of interest

All authors declare no conflict of interest to disclose.

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## Author's contributions

Francesco Saverio Biagiarelli and Umberto Raucci designed the study, coordinated and supervised data collection, interpreted data, drafted the initial manuscript, approved the final manuscript as submitted, and equally contributed to the work.

Simone Piga and Marta Luisa Ciofi degli Atti, participated in the design of the study performed statistical analysis, interpreted data, reviewed and revised the manuscript, and approved the final manuscript as submitted.

Angelo Aulisa and Paolo Schingo participated in the design of the study, collected and interpreted data, reviewed and revised the manuscript, and approved the final manuscript as submitted.

Antonino Reale, Pasquale Parisi, Chiara Ossella and Maria Pia Villa, participated in the design of the study, participated in critically revising the intellectual contents of manuscript, and approved the final manuscript as submitted.

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