Early diagnosis of thoracolumbar spine fractures in children. A prospective study

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Summary

Introduction: Early detection of spine fractures in children is difficult because the clinical examination does not always raise worrisome symptoms and the vertebrae are still cartilaginous, and consequently incompletely visualized on routine X-rays. Therefore, diagnosis is often delayed or missed.

Hypothesis: The search for a "breath arrest" sensation at the moment of the trauma improves early detection of thoracolumbar spine fractures in children.

Materials and methods: This was a prospective monocentric study including all children consulting at the pediatric emergency unit of a single university hospital with a thoracolumbar spine trauma between January 2008 and March 2009. All children had the same care. Pain was quantified when they arrived using the visual analog scale. Clinical examination searched for a "breath arrest" sensation at the moment of the trauma and noted the circumstances of the accident. X-rays and MRI were done in all cases.

Results: Fifty children were included with a mean age of 11.4 years. Trauma occurred during games or sports in 94% of the cases. They fell on the back in 72% cases. Twenty-three children (46%) had fractures on the MRI, with a mean number of four fractured vertebrae (range, 1–10). Twenty-one of them (91%) had a "breath arrest" sensation. Fractures were not visualized on X-rays in five cases (22%). Twenty-seven children had no fracture; 19 of them (70%) did not feel a "breath arrest". Fractures were suspected on X-rays in 15 cases (56%).

Discussion: The search for a "breath arrest" sensation at the moment of injury improves early detection of thoracolumbar spine fractures in children (Se = 87%, Sp = 67%, PPV = 69%, NPV = 86%).

KEYWORDS
Fracture; Spine; Children; Detection; Clinical; MRI
Introduction

Thoracolumbar spine fractures are rare in children. For Hubbard et al. [1], they account for less than 1% of skeletal injuries and for Behrooz et al. [2] 3% of all injuries in children. The gap in the statistics of the different studies suggests that the common criteria defining thoracolumbar fractures in children remain to be clarified and that certain types are underestimated.

In children, the clinical examination often errs on the reassuring side. In addition, the cartilaginous structures of the vertebrae in children are weak areas and their fracture often goes undetected on standard X-rays [3]. Finally, the specific anatomical and physiological features of the spine in children must be taken into account. The posterior joint surfaces are more horizontal in the young child than in the adult, which increases the risk of anteroposterior displacements in injuries [4]. The nucleus pulposus is more hydrated in children than in adults [5] and absorbs shocks more efficiently the younger the child is.

Spinal fractures in children therefore differ from such fractures in adults in their type, their location, and the consequences that they can cause on spinal growth. For Ogden [4], this is most often multileveled vertebral compression resulting in what he terms a true “plastic fracture of the spine” [6].

For these reasons, the diagnosis of thoracolumbar spine fractures in children is frequently delayed and their frequency underestimated. In autopsies of children with thoracolumbar spinal injury, Aufdermaur found fractures of the spine in 12 children, even though the radiological diagnosis had been made in only a single case [7]. In addition, in a prospective study including 228 patients, Junkins et al. [8] showed that the clinical diagnosis of thoracolumbar fractures in children had 81% sensitivity and 68% specificity. Finally, Epstein and Epstein showed that lumbar spine fractures in children were only diagnosed a mean 6 weeks after injury [9].

Our experience has allowed us to note that a high number of children treated for thoracolumbar spine fractures experienced a “breath arrest” sensation at the time of injury, contrary to children whose injury did not result in fracture. We, therefore, wished to study the correlations between the “breath arrest” sensation at the time of trauma and the presence of thoracolumbar spine fractures in children to determine whether this clinical sign, as yet never described in the literature, could improve the early diagnosis of thoracolumbar spine fractures in children.

Material and methods

This was a prospective single-centre study that included all children admitted to the paediatric emergency unit of the Nice University Hospital for thoracolumbar spine injury, excluding multi-trauma victims, between January 2008 and March 2009. Fifty children were included and treated according to the defined protocol.

Upon arrival, the child was examined in the emergency unit by one of the department’s two paediatric orthopaedic surgeons, who collected the following clinical data:

- pain (evaluated by the intake nurse) with the visual analog scale (VAS);
- circumstances of the accident;
- lesion mechanism;
- search for the “breath arrest” sensation at the time of the accident: the child was asked if he had had a sensation of “breathlessness” a few seconds immediately following his injury;
- clinical examination (inspection and palpation of the spine looking for painful points);
- neurological examination (motricity, sensitivity, tonicity, osseotendinous reflexes).

Plain AP and lateral X-rays of the thoracic and lumbar spine were taken in the emergency unit looking for direct or indirect radiographic signs of fracture. Other than the cuneiform aspect (Figs. 1 and 2) or a decrease in the height of one or several vertebrae compared to the adjacent vertebrae levels, plain X-rays were used to search for retracted displacement of the posterior wall, a loss of congruence of the posterior joint surfaces, or a scoliotic posture resulting from muscle contracture (Fig. 3). The plain X-rays were interpreted in the emergency unit by the surgeon based on three items: “absence of bone lesion”, “suspected bone lesion(s)”, and “presence of bone lesion(s)”. Then all the children included in the study underwent a delayed emergency MRI of the thoracolumbar spine performed with a 1 Tesla MRI equipped with a specific antenna for the spine. Two sagittal sequences were systematically taken: T2 STIR (with fat suppression) to screen for bone fracture lesions showing as hypersignals (Fig. 4) and T1 TSE for a more detailed analysis of the morphology (cuneiform aspect and height reduction) of the vertebrae marked by a hypersignal on the preceding sequence (Fig. 5). Finally, if a retracted posterior wall was visualized on the preceding sagittal sequences, the study’s protocol provided for taking a T2-axial sequence to assess the relations between the fractured vertebrae and the spinal cord or the nerve roots.

Next, two groups were formed based on whether the MRI was normal (Group N) or pathological (Group P).

The statistical analyses were performed using Statview 5.0 software (SAS Institute, Cary, NC, USA). The significance threshold retained was $P < 0.05$. The analysis of the correlations between the qualitative parameters (presence or absence of fracture on the plain X-rays or MRI, presence or absence of the notion of “breath arrest”) was performed...
Results

The accident occurred during play or sports activity in 94% of the cases and a fall flat on the back in 72% of the cases. None of the patients had neurological damage. The “breath arrest” sensation was found in 58% of the cases. Whatever the child’s age, none hesitated to identify the sensation of breathlessness when it had been perceived.

The MRI found bone lesions in 23 patients (Group P) and confirmed the absence of lesions in 27 patients (Group N) (Table 1). The only bone lesions observed were vertebral compression or cancellous bone fractures. The statistical analysis showed that the proportion of fractures visualized on X-rays of Group P children was significantly greater than the proportion in Group N children ($P=0.01$) (Table 1).

MRI showed the presence of fractures in 29% of the cases in which X-rays were normal (Table 1). The Group N and P populations were comparable since the statistical analysis

using the Fisher exact test. The analysis of the quantitative results (age, VAS) between patient subgroups was performed using the Mann-Whitney nonparametric test for unpaired series.

Figure 1  Plain lateral X-ray. Cuneiform vertebral compression of Th6.

Figure 2  Enlargement of Fig. 1 centred on the vertebral compression of Th6.

Figure 3  Plain AP X-ray. Scoliotic position in the context of vertebral compression of Th6.

Figure 4  MRI of thoracolumbar spine. Sagittal T2 STIR sequence. Compression of Th7 and Th8.
found no significant different in sex ratio, age, pain, etiology, or lesional mechanism (Table 1).

The statistical analysis showed that there was a highly significant correlation between the presence of a fracture and the presence of the "breath arrest" clinical sign \( (P < 0.001) \) (Table 1). When the plain X-rays were normal, the absence of "breath arrest" was closely related to the absence of fracture \( (P = 0.01) \) (Table 2).

### Discussion

### Epidemiology

Several authors have observed the existence of two frequency peaks of thoracolumbar spine fractures in children: between 0 and 5 years of age and then after 10 years \([10–12]\). In this study, the children's mean age was 11.4 years and we did not find a frequency peak for one or the other of these two age groups (Fig. 6). The present study included few adolescent cases. In our institution, most of the multi-trauma victims are treated by the adult emergency unit and are not part of our activity. No statistically significant correlation was demonstrated between age and the presence of vertebral compression.

According to the literature, injuries to the thoracolumbar spine mainly occur, in descending order of frequency, during a motor vehicle accident, a fall from a height, sports accidents, and child abuse \([13–16]\). In the present series, the vast majority of the thoracolumbar spine injuries occurred during play or sports activities (94%) with a dominating share in skiing or sledding accidents, responsible for 30% of all the

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<thead>
<tr>
<th>Table 1</th>
<th>Distribution of results.</th>
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<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td><strong>Number of cases</strong></td>
<td>50</td>
</tr>
<tr>
<td><strong>Males/females</strong></td>
<td>24/26</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>11.2 ± 1.2</td>
</tr>
<tr>
<td><strong>Pain (VAS)</strong></td>
<td>1.2 ± 1.2</td>
</tr>
<tr>
<td><strong>Etiology</strong></td>
<td></td>
</tr>
<tr>
<td>Skiing</td>
<td>15 (30%)</td>
</tr>
<tr>
<td>Other sports and games</td>
<td>32 (64%)</td>
</tr>
<tr>
<td>Motor vehicle accident</td>
<td>3 (6%)</td>
</tr>
<tr>
<td><strong>Mechanism</strong></td>
<td></td>
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<tr>
<td>Fall on the back</td>
<td>36 (72%)</td>
</tr>
<tr>
<td>Direct injury</td>
<td>5 (10%)</td>
</tr>
<tr>
<td>Other</td>
<td>9 (18%)</td>
</tr>
<tr>
<td><strong>Breath arrest sign</strong></td>
<td></td>
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<tr>
<td>Present</td>
<td>29 (58%)</td>
</tr>
<tr>
<td>Absent</td>
<td>21 (42%)</td>
</tr>
<tr>
<td><strong>Plain X-ray</strong></td>
<td></td>
</tr>
<tr>
<td>No visible fracture</td>
<td>17 (34%)</td>
</tr>
<tr>
<td>Suspected fracture</td>
<td>27 (54%)</td>
</tr>
<tr>
<td>Fracture</td>
<td>6 (12%)</td>
</tr>
</tbody>
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<tr>
<th>Table 2</th>
<th>Correlations between X-rays, &quot;breath arrest&quot; sign, and existence of fractures.</th>
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</thead>
<tbody>
<tr>
<td><strong>X-rays</strong></td>
<td><strong>Breath arrest</strong></td>
</tr>
<tr>
<td>No visible fracture</td>
<td>Present</td>
</tr>
<tr>
<td>Absent</td>
<td>7</td>
</tr>
<tr>
<td>Suspected fracture</td>
<td>Present</td>
</tr>
<tr>
<td>Absent</td>
<td>13</td>
</tr>
<tr>
<td>Fracture</td>
<td>Present</td>
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injuries and accounting for 32% of the play or sports accidents (Table 1). This is explained by the nearby winter resorts and our hospital being a reference paediatric trauma centre.

The literature describes the presence of neurological impairment in 20% of children with spinal fracture [17]; however, the neurological exam was normal in all the children included in this study. All the spinal fractures observed in this study were type 1 fractures according to Denis's classification [18,19]. In this type of fracture, neurological complications are exceptional because of the stability and absence of posterior wall retraction.

"Breath arrest" sign

While 91% of the patients who had a fracture also experienced a "breath arrest" sensation, this was found in only 30% of the patients whose MRI was normal. There was a highly significant association between the presence of "breath arrest" and the existence of fractures ($P < 0.001$) (Table 1). Moreover, the statistical analysis demonstrated a close correlation between the presence of a "breath arrest" sensation and the existence of radiologically identifiable fractures ($P = 0.01$) (Table 2). Finally, we showed that in the absence of a radiologically visible fracture, the absence of "breathlessness" was closely related to the absence of fracture ($P = 0.01$) (Table 2).

In absence of a radiologically visible lesion, the absence of "breathlessness" reduced the probability of a fracture, with 26% sensitivity, 100% specificity, a 100% positive predictive value, and a 53% negative predictive value. On the other hand, the "breath arrest" sign was not significantly correlated with age.

The "breathlessness" sensation at the time of the accident is therefore a good clinical sign for screening bone lesions in thoracolumbar spine injuries in children. This sign does not appear in the usual description of the clinical semiology of this type of fracture.

It would therefore be useful to integrate the "breath arrest" sign into all the assessment grids used by intake nurses in paediatric medical and surgical emergency departments. Yet today there is no validated assessment grid at the national level and every paediatric emergency unit has developed its own assessment tool. In the vast majority of cases, the assessment grids in France have taken inspiration from the Canadian Triage and Acuity Scale paediatric guidelines (PaedCTAS), reviewed in 2008 [20], whose computerized version was validated for paediatric emergency departments in 2009 [21].

**Imaging**

Plain X-rays were often taken as a default option. They were interpreted as pathological in only 26% of the children who had a fracture. Similarly, we observed 22% false-negative results in the group of children whose X-rays were considered normal. MRI therefore demonstrated objective bone lesions that had not been detected by conventional imaging. These were cancellous bone fractures that produced functional symptoms with no real bone compression visible on the X-rays. However, in all the cases in which the plain X-rays found at least one fracture with certainty, they were confirmed by MRI. Although there is a highly significant association between the existence of a fracture on plain X-rays and the presence of vertebral compression on MRI ($P = 0.005$), it must be emphasized that in the 23 children who had confirmed bone lesions on MRI (Group P), the mean number of fractures visualized on plain X-rays was 0.3 (range, 0–2) versus 4 (range, 1–10) on MRI.

We believe that CT should not be the choice exam in thoracolumbar spine injuries in children. Indeed, this exam is significantly irritating. Although the effective dose delivered during a CT scan exam is lower in children than in adults, it is nonetheless estimated between 5.8 mSv and 6.51 mSv to study the thoracic spine and between 2 mSv and 12 mSv for the lumbar spine [22–25]. The younger the child, the more harmful this exam is for the child.

Yet in multi-trauma victims, a whole-body scan should be done to search for cranial-encephalic, thoracic, or...
abdominal lesions. Views centred on the spinal cord are taken to search for major lesions of the spinal cord, but the limits of this imaging modality must be well known and one must not hesitate to perform a complementary MRI at the slightest clinical or CT doubt concerning a spinal cord lesion.

Conclusion

In children, the clinical symptoms can be misleading in cases of thoracolumbar spine fractures. The vast majority of fractures correspond to vertebral compression (Denis type 1 [18,19]) that is stable and provokes little pain.

The notion of "breath arrest" at the time of injury should attract the clinician’s attention because this sign is very significantly related to the presence of fracture(s). This "breath arrest" sign should therefore be integrated into the assessment grids in paediatric medical and surgical emergency units.

In addition, MRI shows bone lesions that go undetected on conventional imaging. Furthermore, the cartilaginous structures of children’s vertebrae, which are not directly visible on X-rays, are a diagnostic pitfall. Yet these are also weak areas where the large majority of thoracolumbar spine fractures occur in children [3]. MRI can visualize not only these cartilaginous lesions, but also cancellous lesions, explaining the pain phenomena; the involvement of several vertebrae shows a real "plastic fracture of the spinal cord in children" [6].

Finally, for the first time, this study makes it possible to recommend a strategy for the clinician who treats the paediatric thoracolumbar spine injury victim with no associated neurological impairment. Indeed, if the child did not experience "arrested breath" at the time of injury and the plain X-rays are normal, no complementary exam is necessary because the absence of fracture has been significantly demonstrated.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References