ACTA RADIOLÓGICA PORTUGUESA
January-April 2019 | Vol 31 nº1 | 7-10

Editor Letter / Carta ao Editor

Child Abuse: Bone Scintigraphy for the Evaluation of Non-Accidental Lesions

Abuso Físico na Criança: a Cintigrafia Óssea no Diagnóstico de Lesões Não Acidentais

Ana Rita Fernandes[1], Maria Teresa Faria[1], Ana Oliveira[1], Pedro Barata[2], Jorge Pereira[1]

[1]Department of Nuclear Medicine, Centro Hospitalar Universitário de São João, Porto, Portugal
[2]Faculty of Health Sciences of the Fernando Pessoa University, Porto, Portugal

Adress

Ana Rita Fernandes
Serviço de Medicina Nuclear
Centro Hospitalar Universitário de São João
Alameda Prof. Hernâni Monteiro
4200-451 Porto, Portugal
email: anaritaoliveirafernandes@gmail.com

Abstract

Introduction: Child abuse is a complex problem that must be identified and solved as quickly as possible with a multidisciplinary approach. Bone fractures, usually not life-threatening injuries, are often the strongest indicator of abuse. Medical imaging has thus a crucial role, since fractures are often hidden, with signs and symptoms difficult to interpret, and children may be unable to provide history. Bone scintigraphy has appeared in publications addressing child abuse since the 80's.
Aim: To assess the role of Bone scintigraphy in child abuse.
Results/Discussion: Some guidelines on approaching child abuse already include bone scintigraphy. In our country, its role and its usefulness remain poorly known.
Studies comparing Radiography and Bone scintigraphy showed that scintigraphy was the only method to identify bone lesions in 4 to 20% of patients. Additionally it helped to clarify misleading lesions.
Conclusion: When evaluating the suspicion of child abuse, the method of choice is the X-ray of the skeleton. Reviewing the literature, however, we conclude that there is no ideal method and that Radiography and Bone Scintigraphy play a complementary, non-competitive role.
We therefore propose the regular performance of Bone Scintigraphy when the X-ray does not identify any lesions, when it presents equivocal findings or when accurately determining the number and location of lesions may have a legal impact.

Keywords

Child abuse; Scintigraphy; Fractures.

Resumo

Introdução: O abuso físico em crianças é um problema complexo que deve ser identificado e resolvido o mais rapidamente possível, numa abordagem multidisciplinar. As fraturas são um indicador muito forte de abuso, apesar de, maioritariamente, não causarem risco de vida. Assim, a imagiologia é crucial, uma vez que as fracturas são frequentemente ocultas, com sinais e sintomas difíceis de interpretar, e as crianças nem sempre têm capacidade de fornecer a história. A Cintigrafia óssea na suspeita de abuso físico em crianças surge em publicações desde os anos 80.
Objectivo: Rever o papel da Cintigrafia óssea no abuso infantil.
Discussão: A Cintigrafia óssea está incluída nas *guidelines* de abordagem de crianças vítimas de abuso em alguns países. No nosso país, o seu papel e a sua utilidade estão pouco divulgados.
Estudos comparativos entre a Radiografia e a Cintigrafia óssea demonstraram que a cintigrafia foi o único método capaz de identificar lesões em 4 a 20% dos casos, para além de ajudar a esclarecer lesões equívocas na radiografia.
Conclusão: Na suspeita clínica de abuso infantil, o método de eleição é a Radiografia do esqueleto. Contudo, concluímos que não existe um método ideal único e que a Radiografia e a Cintigrafia óssea apresentam um papel complementar, não competitivo.
Propomos, assim, a realização regular da Cintigrafia óssea, quando a Radiografia não identifica qualquer lesão óssea, quando apresenta achados equívocos ou nos casos em que a determinação exata do número e da localização das lesões possa ter impacto legal.

Palavras-chave

Abuso infantil; Cintigrafia; Lesões não acidentais

Introduction

The definition of abuse changes over time and according to different cultures. In 1999, the World Health Organization defined child abuse/maltreatment as any form of physical and/or emotional ill treatment, sexual abuse, neglect or negligent treatment or commercial or other exploitation, resulting in actual or potential harm to the health, survival, development or dignity of the child, in a context of a relationship of responsibility, trust and power. Of the various types of abuse, physical and emotional are the most frequent ones and, in most cases, concomitant.[1]

The actual incidence of child abuse is unknown. According to the International Society for the Prevention of Child Abuse and Neglect (ISPCAN) of the WHO, it is estimated that 5 children die daily from abuse, more than 1 trillion children experience violence annually, and many more suffer from abuse throughout the rest of their lives. It is estimated that one in four young adults has been severely maltreated during childhood. Finally, it is estimated that up to 55% of children who were fatally abused were evaluated by a health professional the month before the event.[2]
In Portugal, in 2017, the Commission for the Protection of Young People and Children (CPCJ) monitored 69,967

cases, 35,075 of which were newly diagnosed. Non-accidental injuries caused by physical abuse were frequent, being the 5th cause of intervention of the CPCJ (1,086 cases were registered, 488 new situations of physical abuse diagnosed in 2017). Of these, the following cases stand out: physical offense, corporal punishment offense and female genital mutilation.

Although fractures are not often life-threatening to a child victim of abuse, they are usually the strongest indicator of abuse.[3,4] In this context, correct diagnosis and guidance of children is fundamental.

Materials and methods

The authors reviewed the articles and guidelines published until 2017, based on the following keywords in PubMed and Google: child abuse; Bone Scintigraphy; non-accidental injuries; fracture/non-accidental fracture.

A review of the state of the art on the subject is presented below.

Discussion

Lesion evaluation

In a situation of suspected physical abuse, besides skin lesions, bone lesions are the most common finding and may involve the entire skeleton. Bone fractures are detected in little more than half of the children investigated[2] and, in many cases, are not accompanied of external physical findings (e.g. hematoma, ecchymosis).[5]

However, if fractures are a common sign of abuse, they are also a frequent finding of accidental trauma. So, accurate evaluation of the fracture is essential, strictly practiced by experienced physicians, with anamnesis playing a key role.[5]

The child's age and height are predictive of the trauma mechanism and, consequently, of the type of injury suffered. For example, the older and larger the child, the greater the likelihood of lesions on the extremities.[6,7] Most cases of non-accidental fractures occur in children under the age of three; the prevalence of these fractures decreases with increasing age.[6]

Bone fractures more suggestive of physical abuse include those in the costal arches, classic metaphyseal injuries, fractures inconsistent with the child's story or age, multiple fractures involving more than one skeletal area, and fractures with different ages of consolidation.[2,5,6,8,9]

The approach of an abused child should be multidisciplinary. Imaging plays a crucial role since fractures are often hidden and occur in children who are unable to provide a story of events, with signs and symptoms difficult to interpret.[7,8] Medical imaging may document the number, extent and severity of bone lesions, as well as date them.[6]

The role of the medical image

Both Radiology, with skeletal radiography, and Nuclear Medicine, with Bone Scintigraphy, allow the detection of lesions suggesting abuse and help in the differential diagnosis between accidental and non-accidental lesions.[9]

Conventional radiography is the first-line examination, both in the identification of new cases and in the follow-up of suspected cases.

All this information has important legal and social implications.

Bone Scintigraphy, in this context, has appeared in publications since the early 1980s. Already established in the diagnosis of bone fractures, it may be useful in investigating suspected physical abuse, being included in the diagnostic algorithms of the United Kingdom (UK)[10] and the United States of America (USA)[11] guidelines and routinely used in some centers.[2] In Portugal, its role is not yet standardized.

Bone Scintigraphy

By administering a radiopharmaceutical composed of diphosphonates marked with radioactive technetium ([^{99m}Tc]Tc-diphosphonates), Bone Scintigraphy allows the identification of osteoblastic activity and the evaluation of the entire skeleton.

Bone Scintigraphy is a very sensitive examination for osteoblastic lesions, with the ability to detect them early - a few hours after the trauma (before X-ray) - and over a period of, at least, 6 months. In certain cases, it identifies bone changes several decades after the trauma and is, therefore, not ideal for dating fractures,[2] on the other hand it has the capacity to detect both recent and old fractures in cases of prolonged abuse.

The main advantage of Bone Scintigraphy is the identification of occult lesions, which are difficult to visualize in Radiography. Examples of these are micro-trabecular fractures, plastic deformities, stress lesions,[6] those of small dimensions and those located in complex anatomical structures, with overlapping images (scapula, hands, costal arches, mainly along the chondro-costile cartilages, pelvis and feet), or in structures with low bone density.[2,6,4,7,8,9,10,12] Bone Scintigraphy also plays an important role in cases of "bone contusion", characterized by lesions in the periosteum and minimal cortical damage.[2,6,10] Conversely, Bone Scintigraphy is less sensitive than radiography in the detection of classic metaphyseal lesions - a site of physiological osteoblastic hyperactivity - and of skull fractures.[2,4,7,9,10]

Bone Scintigraphy has also the advantage of revealing extra-osseous lesions, possibly asymptomatic and/or unapparent in other exams, such as intracranial (e.g., cerebral infarction), visceral (e.g., renal contusion) and soft tissue lesions (especially muscular).[2,3,4,7,14] The physiopathological mechanisms that lead to extra-osseous capture of the radiopharmaceutical include the expansion of extra-cellular fluid, increased vascularization, increased regional permeability, and increased calcium concentration in the tissues.[13]

A disadvantage of Bone Scintigraphy is its reduced specificity. Abnormal findings may relate to the presence of infection or malignancy.[15] However, specificity increases significantly with the integration of clinical history (Bayes's Theorem) and with the experience of the imaging specialist.

Its cost, higher than that of conventional Radiography, is another reason pointed out against the use of Bone Scintigraphy, but it can be argued that costs should be assessed taking into account the overall benefit to the patient, including the potential diagnosis of lesions not shown in the radiological study and the potential legal benefits.[6]

Another criticism/disadvantage attributed to scintigraphy in children is the possible need for sedation. However, in most services where pediatric studies are often performed, sedation is only sporadically needed, usually for longer time consuming tests.

Another major question clinicians generally have about Nuclear Medicine exams is the amount of radiation the child is exposed to. All examinations using ionizing radiation follow the ALARA (As Low As Reasonable Achievable) principle for exposure to radiation, that is, as low as reasonably possible. The effective dose of radiation to which the child is exposed by conventional radiography is between 0.18 and 2.76 mSv.[7] In Nuclear Medicine, the dosage is calculated taking into account the child's weight; in Bone Scintigraphy, the effective dose for a child will be between 2.0 and 2.5 mSv.[15] In addition, the radiation dose administered allows the acquisition of full-body images, as well as any other detailed images or tomographic images deemed necessary, without exposing the child to additional radiation.

Guidelines from countries that routinely use Bone Scintigraphy

In the suspicion of non-accidental lesions in the child, Bone Scintigraphy appears integrated in the guidelines of the USA and the UK, being routinely performed in several centers.

In the USA, the American College of Paediatrics states that, in selected cases, Bone Scintigraphy may offer a diagnostic alternative or be used in conjunction with radiography; particularly in children over one year of age, it may increase sensitivity for the detection of costal arch fractures, subtle diaphysis fractures and periosteal elevation areas.[11,16]

The American College of Radiology, in the publication "Appropriateness criteria in suspected physical abused-child", reviewed in 2016, highlights the usefulness of Bone Scintigraphy in cases where there is clinical suspicion of abuse and where the Radiography is negative or equivocal.[8]

In the UK, the Royal College of Radiologists, together with the Royal College of Paediatrics and Child Health, published guidelines for the approach and follow-up of children with suspected non-accidental injuries in March 2008. These guidelines recommend the use of Bone Scintigraphy when the X-ray presents equivocal findings or when it is negative, but a strong clinical suspicion of abuse remains. They reaffirm that the role of the two methods is complementary and that both may identify more skeletal lesions than each performed alone. Bone Scintigraphy is also the preferred method when a skeletal follow-up radiograph (performed after 11 to 14 days) is not feasible (either because of child safety concerns during those days or because of the child's probable absence on the examination date).[10]

Published comparative studies

In the literature, there are studies comparing the diagnostic capacity of Bone Scintigraphy with that of Skeletal Radiography in children victim of physical abuse.

In 1983, John Sty published a study that included 261 children who underwent Skeletal Radiography and Bone Scintigraphy for suspected physical abuse. Of the total, 141 presented both studies negative. Of the 120 children with positive studies, Skeletal Radiography diagnosed one or more fractures in 105 children, while Bone Scintigraphy detected one or more fractures in 120 children [15 children (12.5%) with fractures detected only in scintigraphy].

This study also demonstrated that Bone Scintigraphy contributed to the diagnosis of additional fractures in 17 children who had not been identified in Skeletal Radiography. Bone Scintigraphy did not diagnose two fractures that were identified in the radiographic study.[17]

In 1993, Conway et al reviewed the clinical processes of 99 hospitalized children who were discharged with a diagnosis of child abuse and 330 children referred for Bone Scintigraphy on suspicion of physical abuse. The authors concluded that they are complementary methods, since some lesions were only detected by one of the techniques (compared with conventional Radiography, Bone Scintigraphy had greater sensitivity in the detection of soft tissue and bone trauma), suggesting that both techniques should be performed in children younger than 2 years of age, considered to be the most vulnerable group.[6]

A 2003 retrospective study included 124 children diagnosed with non-accidental injuries. Of these, 32 children underwent Bone Scintigraphy and Skeletal Radiography. The analysis showed that 70% of the lesions were detected in both examinations, but that 20% were only detected by Bone Scintigraphy and 10% only by conventional radiography. Bone Scintigraphy showed greater sensitivity in the detection of pelvic lesions, costal arches and radius, and limitations in the detection of cranial lesions and classic metaphyseal lesions. This study also concluded that radiography and Bone Scintigraphy have a complementary role in suspected bone lesions.[4]

A meta-analysis of 2006, conducted by Kemp, A.M. et al, included 34 studies, with children and adolescents up to the age of 18. It was found that, in 56 cases, fractures would not have been detected if both examinations had not been performed. Of the 34 studies, 15 directly compared the diagnostic capacity of both modalities. In 14/15, the X-ray or the Bone Scintigraphy individually, were insufficient for the diagnosis. In 5/15, Bone Scintigraphy proved to be more sensitive. This meta-analysis confirmed that both Radiography and Bone Scintigraphy are useful in investigating occult fractures, but that if performed individually, they will leave fractures undetected.[7]

In 2015, University Hospital of Wales Cardiff, which by routine uses Bone Scintigraphy in conjunction with Skeletal Radiography, has published a 10-year retrospective study reviewing the processes of children under the age of two investigated for suspected abuse. Skeletal Radiography was performed in 237 children and Bone Scintigraphy in 173. Bone Scintigraphy identified hidden lesions in 12% of the cases in which it was performed. In the group of children who underwent Bone Scintigraphy and Radiography (166 children), Bone Scintigraphy aided in the diagnosis of equivocal lesions in Radiography in 14 children. In 4% of the cases (7 children), lesions were only detected in Bone Scintigraphy.[2]

Overall, these comparative studies demonstrate the importance of Bone Scintigraphy, since in 4% to 20% of the children victim of abuse, only Bone Scintigraphy has identified lesions.[2,4,6,18]

Given the complementary nature of both studies, there are those who argue that Bone Scintigraphy should be requested, even when the radiological study is positive, since the severity of the abuse is determinant for legal and social purposes.[4,6]

PET-CT with [^{18}F]Sodium fluoride in the investigation of suspected abuse

Recently, Nuclear Medicine has another method to evaluate bone lesions: positron emission tomography (PET) with [^{18}F]Sodium fluoride. In the guidelines of the European Society of Nuclear Medicine, one of the indications listed for this examination is the evaluation of bone fractures in child victims of abuse.[19]

In physiopathological terms, PET with [^{18}F]Sodium fluoride is an examination similar to Bone Scintigraphy, but it uses equipment and a radiopharmaceutical with greater sensitivity and better diagnostic accuracy.

At Children's Boston Hospital, Bone Scintigraphy is no longer used and PET is performed with [^{18}F]Sodium fluoride. In a retrospective study published in 2010, which included 22 children under 2 years old, 156 fractures were detected by Skeletal Radiography and 200 fractures by PET. Of the 44 fractures that were only diagnosed by PET, the majority was located in the thorax (posterior costal arches).[20]

This technique presents higher sensitivity and may be reserved for cases of high clinical suspicion of physical abuse in the absence of identifiable lesions through other available methods.

Conclusion

The first-line diagnostic method on suspicion of non-accidental bone lesions is the X-ray of the skeleton. However, after this bibliographic review, we conclude that there is no single ideal method and that conventional radiology and Bone Scintigraphy play a complementary, noncompetitive role.

Thus, we propose the regular performance of Bone Scintigraphy when in the presence of clinical suspicion of child abuse, particularly when the radiographic study does not identify lesions, when the study presents equivocal findings or when accurately determining the number and location of lesions may have an impact on the legal process.

Received / Recebido 26/03/2018
Acceptance / Aceite 22/11/2018

Ethical disclosures / Divulgações Éticas
Conflicts of interest: The authors have no conflicts of interest to declare.
Conflitos de interesse: Os autores declaram não possuir conflitos de interesse.
Financing Support: This work has not received any contribution, grant or scholarship.
Suporte financeiro: O presente trabalho não foi suportado por nenhum subsídio ou bolsa.
Confidentiality of data: The authors declare that they have followed the protocols of their work center on the publication of data from patients.
Confidencialidade dos dados: Os autores declaram ter seguido os protocolos do seu centro de trabalho acerca da publicação dos dados de doentes.
Protection of human and animal subjects: The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).
Protecção de pessoas e animais: Os autores declaram que os procedimentos seguidos estavam de acordo com os regulamentos estabelecidos pelos responsáveis da Comissão de Investigação Clínica e Ética e de acordo com a Declaração de Helsínquia da Associação Médica Mundial.

Referências

1. Krug EG, Dahlberg LL, Mercy JA, Zwi AB, Lozano R. Child abuse and neglect by parents and other caregivers. In: World Report on Violence and Health. 2002:57.
2. Bainbridge JK, Huey BM, Harrison SK. Should bone scintigraphy be used as a routine adjunct to skeletal survey in the imaging of non-accidental injury? A 10 year review of reports in a single centre. Clin Radiol. 2015;70:e83-e89.
3. U.S. Department of justice. Diagnostic Imaging of Child Abuse. 2000.
4. Mandelstam SA, Cook D, Fitzgerald M, Ditchfield MR. Complementary use of radiological skeletal survey and bone scintigraphy in detection of bony injuries in suspected child abuse. 2003;16:387-90.
5. Rijn RR Van, Sieswerda-Hoogendoorn T. Educational paper: Imaging child abuse: the bare bones. Eur J Pediatr. 2012;171:215-24.
6. Conway J, Collins M, Tanz R, et al. The role of bone scintigraphy in Detecting Child Abuse.pdf. Semin Nucl Med. 1993;XXIII:321-33.
7. Kemp AM, Butler A, Morris S, et al. Which radiological investigations should be performed to identify fractures in suspected child abuse? Clin Radiol. 2006;61:723-36.
8. American College of Radiology Suspected Physical Abuse – Child. 2016:1-15.
9. Offiah A, Van Rijn RR, Perez-Rossello JM, Kleinman PK. Skeletal imaging of child abuse (non-accidental injury). Pediatr Radiol. 2009;39:461-70.
10. The Royal College of Radiologists and Royal College of Paediatrics and Child Health. Standards for Radiological Investigations of Suspected Non-Accidental Injury. 2008.
11. Di Pietro MA, Brody AS, Cassady CI, et al. Diagnostic imaging of child abuse. Pediatrics. 2009;123:1430-5.
12. Barcenilla AJC, Sainz de la Maza VT, Fernandéz JP. Utilidad de la gammagrafía ósea en el diagnóstico diferencial del maltrato infantil. An Pediatr. 2006;65:83-90.
13. Peller PJ, Ho VB, Kransdorf MJ. Extraosseous Tc-99m MDP uptake: a pathophysiologic approach. Radiographics. 1993;13:715-34.
14. Howard JL, Barron B, Smith GG. Bone scintigraphy in the evaluation of extraskeletal injuries from child abuse. Radiographics. 1990;10:67-81.
15. Van den Wyngaert T, Strobel K, Kampen WU, et al. The EANM practice guidelines for bone scintigraphy. Eur J Nucl Med Mol Imaging. 2016;43:1723-38.
16. Kellogg ND. Evaluation of suspected child physical abuse. Pediatrics. 2007;119:1232-41.
17. Sty JR, Starshak RJ. The role of bone scintigraphy in the evaluation of the suspected abused child. Radiology. 1983;146:369-75.
18. PK J. Comparison of radiography and radionuclide bone scanning in the detection of child abuse. Pediatrics. 1984;73:166-8.
19. Segall G, Delbeke D, Stabin MG, et al. SNM Practice guideline for sodium ^{18}F-Fluoride PET/CT bone scans 1.0. J Nucl Med. 2010;51:1813-20.
20. Drubach LA, Johnston PR, Newton AW, Perez-Rossello JM, Grant FD, Kleinman PK. Skeletal trauma in child abuse: detection with ^{18}F-NaF PET. Radiology. 2010;255:173-81.