“Seeing is believing”: myth or maxim? Mimics of pathology on paediatric chest imaging studies

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Shareable abstract (@ERSpublications)
Radiography is a difficult job and not every imaging study is perfectly performed, especially in paediatric cases. This case series highlights the importance of correct interpretation of radiological studies and recognising that all is not what it seems. https://bit.ly/3r4qBSU

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Abstract

Appreciating the importance of correct interpretation of radiological studies, the need for space for further education and experience, and the recognition that interpretative errors often occur, we present below a case series highlighting situations where all may not be as it first appears.

Introduction

There is no question that radiology has revolutionised modern medical diagnostics. The history of modern radiology started in December 1895 [1], when considerable deliberation over the novel properties of radiation and its ability to penetrate screens of substantial thickness culminated in the birth of the X-ray, *via* Wilhelm Röntgen. It was named so, due to its unclear nature [1]. Ironically, despite the intention to improve the assessment of diagnostic conundrums, imaging can still be difficult to interpret and, even more than 100 years on, sometimes lead to a diagnosis of significant abnormality when none is present.

Diagnostic miscalculations are not uncommon and are reported to occur in ∼3–5% of day-to-day analyses [2]. Paediatric imaging holds unique challenges in both the execution of the investigations but also in the interpretation, due to the evolving nature of disease differentials and imaging findings, which can be dependent upon the age of the child.

A retrospective study in a large academic children’s teaching hospital reviewed data on cases identified as having clinically relevant diagnostic inaccuracies, over a period of 10 years. They concluded that errors were multifactorial in their cause and that staff were often involved (45%), noting that factors such as multitasking and interruptions influenced errors and outcomes [3]. They also reported that within their paediatric data, radiography and computed tomography (CT) were most often implicated in inaccuracies [3]. Augmenting these challenges is the generally accepted recommendation of minimising follow-up radiographs and additional imaging, in order to mitigate radiation exposure in keeping with the practice of ALARA (as low as reasonably achievable) [4]. This is argued to be especially present in paediatric thoracic imaging [4].

Furthermore, litigation against misdiagnoses has represented the commonest group of cases within radiology, for decades [5]. More recently, a review of paediatric radiology malpractice still notes that disputes related to misdiagnosis constitute up to 70% of the claims [6] and again, radiography was most often the accused [6]. Thus, although errors are not intentional, the potential for litigation and lawsuits in addition to the possible clinical harm, necessities that we regularly and meticulously review practices to mitigate inaccuracies.

Miscalculations in diagnosis may result from a variety of factors, including technical errors, visual fatigue and inattentional blindness, the latter describing the phenomenon of overlooking an unanticipated occurrence because of being occupied with a different task. Moreover, the dual process theory of reasoning for decisions made in real-life offers further insight [7]. In the context of radiology, this has been described to acknowledge that type 1 (or automatic) practices come into play when a condition is readily recognised, while type 2 processes, denoting a more complex and critical approach, are employed if the diagnosis is challenging [7]. A dynamic interchange between the two processes may be used when making decisions [7]. While arguably both systems are subject to errors, type 1 thinking is more susceptible to this, resulting from the cognitive shortcuts inherent to this process [7].

Finally, there can be no doubt that integral to building the foundations for the best use of radiology is knowledge and practice. In order to generate enough experience for pattern recognition that would lend itself to type 1 thinking, yet also be able to appreciate the nuances that might deceive the inexperienced, exposure to the right learning is required, and this is often insufficiently practised. A study documented that only 0.3% (59 h of the total 19 325 h) of the scheduled medical student teaching timetable was dedicated to radiology [8], while another study reported that 77% of junior doctors wanted more radiology teaching [9].

Therefore, with collective appreciation of the importance of correct interpretation of radiological studies, the need for space for further education and the recognition that interpretative errors often occur, we present below a case series highlighting situations where all may not be as it first appears, or "It ain't necessarily so!" (George and Ira Gershwin, *Porgy and Bess*).

The authors' recommendation

For each case read the short presenting history, examine the image and preferably write down your findings before reading on. There is an assumption that the reader is acquainted with the systematic approach to reviewing chest radiographs and thus, we do not go into detail on how a methodical approach should be carried out. However, there is useful literature detailing practical approaches to chest radiographs, including for paediatric patients [10], which may be a beneficial adjunct to this review.

The very real fictitious pathology

Case 1

An 18-month-old child with cough, shortness of breath and fever (figure 1).

Initial thoughts

Easy to appreciate is the relatively large right pleural effusion that is present with consolidation behind the right hemidiaphragm (within the right lower lobe) and at the base of the left lower lobe (obliterating the medial diaphragmatic contour). However, there is also a large apparent "cavity" in the left upper lobe, with

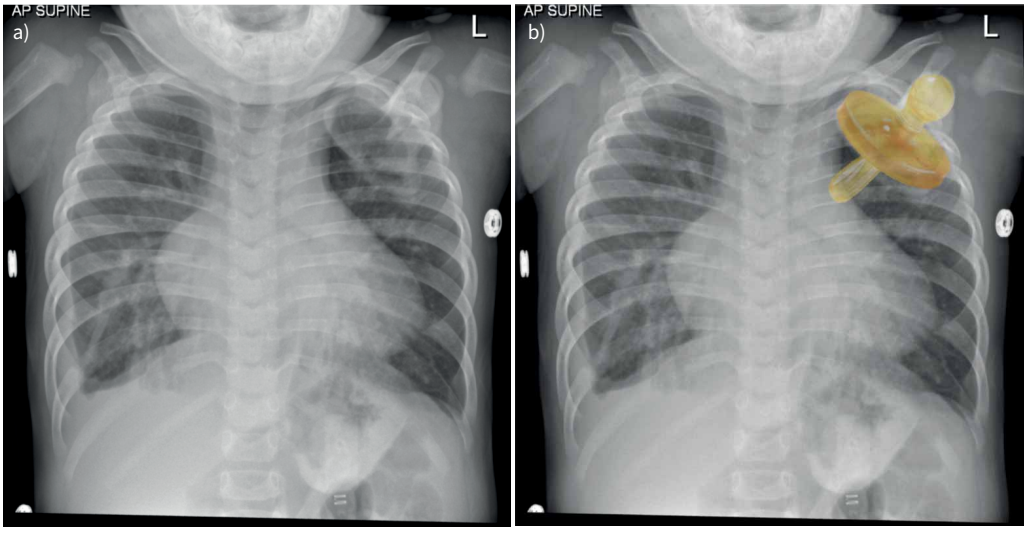

FIGURE 1 a) Chest radiograph; b) chest radiograph with dummy overlay.

an abnormal bone-like structure projecting into the left axilla. The question for the interpretation then is what the differential might include, and whether this is a pulmonary or extrapulmonary pathology. Exploring the pulmonary differentials, could this be a pulmonary "cavity" secondary to, for example, an abscess, cavitating infection (like tuberculosis (TB)) or fungal infection? Or could this instead be an undiagnosed cystic pulmonary airway malformation (CPAM), presenting for the first time with a super-added infection? Or perhaps the diagnosis is extrapulmonary, and this is a bony-appearing structure related to an osteochondroma with or without malignant transformation?

The answer

The right pleural effusion and bi-basal consolidation are genuine and could explain the symptoms. However, on closer inspection of the "cavity"-like structure, the left apical lesion is in fact a dummy or pacifier, helpfully positioned on the infants left shoulder at the time of imaging! It is so well delineated because it is surrounded by air forming a clear interface with the adjacent plastic and rubber. The obvious learning from this case is that whenever clinically safe to do so, all external objects should be removed from the body of the patient prior to imaging. It is a simple yet crucial reminder.

Case 2

A two-year-old with a wet cough (figure 2).

Initial thoughts

The first observation to make is that the lung apices have not been imaged fully; therefore, it is hard to appreciate the entire pulmonary picture. Next, we can immediately appreciate that there is a large, lobulated mass projected over the right lung base, containing dense areas of apparent ossification with an abnormality of the adjacent ribs. After approaching this diagnostic query systematically, we may consider whether this is a large malignancy, such as a teratoma? The ribs also appear to have a usual appearance, with smaller bony projections from the ninth rib. Should we obtain some further imaging (CT or magnetic resonance imaging (MRI))? The nasogastric (NG) tube, however, is reassuringly in the stomach.

The answer

Clearly some further imaging is needed, since around a third of the child's lungs have not been imaged! However, some potentially significant pathology is still demonstrated. There are small lines at the left lung base with loss of clarity of the left hemidiaphragm: subsegmental atelectasis (*i.e.* this is not a normal chest radiograph). As for the lobulated mass, it commences within the chest wall, and then extends beyond the chest wall and on closer inspection contains phalanges and metacarpal bones (the apparent bony projections). The lobulated mass is the child's hand held over the chest. The child wriggled free from their parent's restraint as the film was exposed, and moved part way off the X-ray cassette.

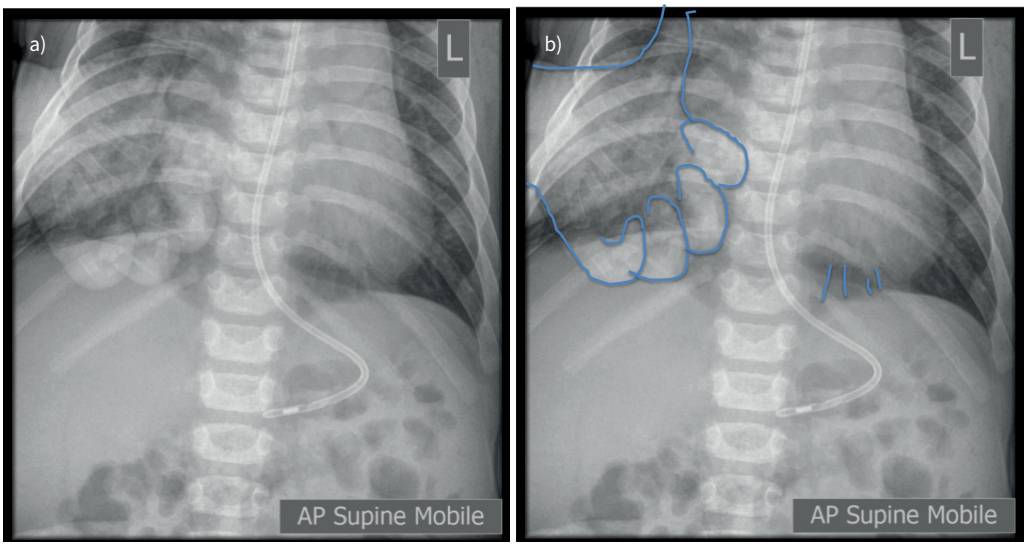

FIGURE 2 a) Chest radiograph; b) chest radiograph with hand outlined.

Case 3

An 8-month-old admitted with poor feeding in whom a chest radiograph was performed to confirm adequate NG tube positioning (figure 3).

Initial thoughts

Immediately, your vision is drawn to the NG tube that has looped on itself and returned to the top of the image. Although confusingly, the tip still appears to be in the stomach. Is there perhaps a second tube (for example, a naso-jejunal tube) which has coiled up in the oesophagus? Both heart borders look less defined than expected, right more than the left.

The answer

There is linear atelectasis and bronchial wall thickening throughout both lungs, probably representing the lower respiratory tract infection for which the child was being treated.

On closer inspection of the image, you will also hopefully appreciate that there is only one tube. The tip of this NG tube is in stomach, but there is a part of the tube which is outside of the child, and it is looped over the front of the chest and has not been moved to one side at the time of the radiograph. The obvious learning again from this case is that wherever clinically safe to do so, all external objects should be removed from the body of the patient prior to imaging. Again, a simple yet time-saving reminder!

Case 4

A 14-year-old with a lingering cough (figure 4).

Initial thoughts

On first inspection, you might appreciate that there is an apparent increase in opacification of the peripheral right lung parenchyma. On closer review, there is also a small mass-like opacity at the right lung base. It is quite dense appearing and irregular in outline. Systematically working through differentials of whether this is likely to be a pulmonary or extrapulmonary pathology, you might query if this is perhaps a large granuloma from TB or histoplasmosis? Is it an osteosarcoma or other calcified metastasis and, therefore, an investigative work-up to identify the primary source should be considered? Perhaps the differential should be wider, and so could it be an arterio-venous malformation, in which case is the heart and pulmonary arterial trunk a bit enlarged?

The answer

Alas, on further inspection, the right basal opacity has a large plait extending from it, right off the top of the image. The opacity is in fact a hair elastic in a 14-year-old with a long plait. Hair braids, *etc*. should ideally be held up out of the field of view at the time of the X-ray acquisition. By this point, it is pretty

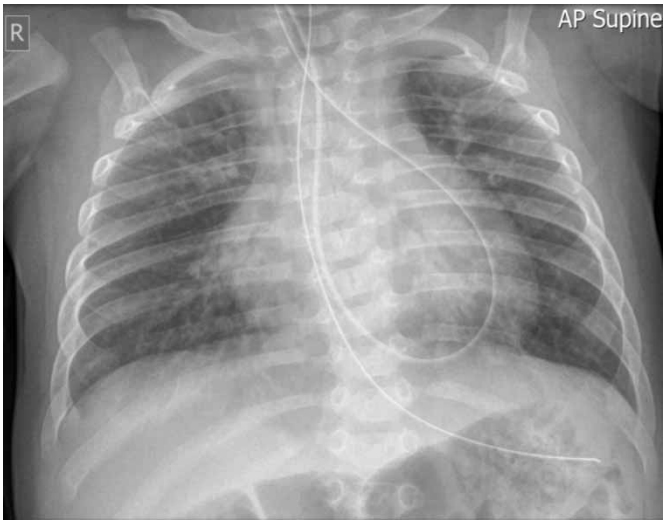

FIGURE 3 Chest radiograph.

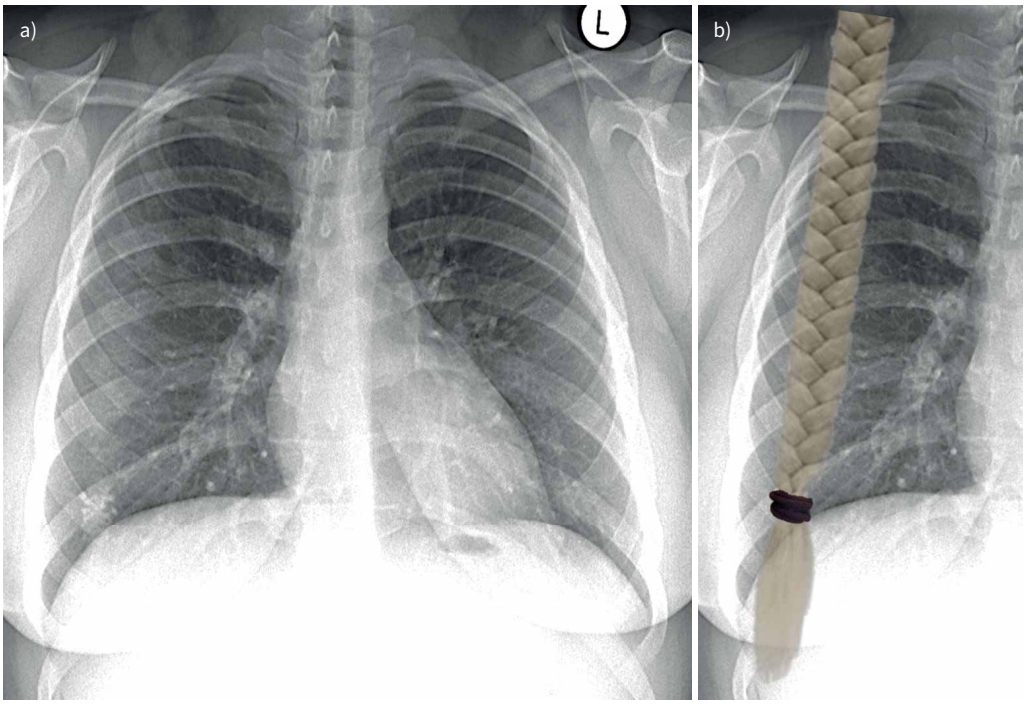

FIGURE 4 a) Chest radiograph; b) chest radiograph with plait superimposed.

clear what the learning point will be (always simple, yet always crucial); although there is very little a radiographer can do if the child happens to let go as the radiograph is exposed!

The positional inquiry

Case 5

A 3-year-old with recurrent lower respiratory tract infections who underwent general anaesthetic CT to assess for bronchiectasis (figure 5).

Initial thoughts

Figure 5a represents a single axial CT slice which demonstrates extensive bilateral upper lobe atelectasis (outlined in blue) and some central bronchial wall thickening (arrow). A differential that might immediately come to mind is whether this severe chronic aspiration? Or perhaps, the patient might be acutely unwell and the changes represent an intercurrent and ongoing pneumonia? Thinking ahead, would a bronchoscopy and bronchoalveolar lavage be indicated?

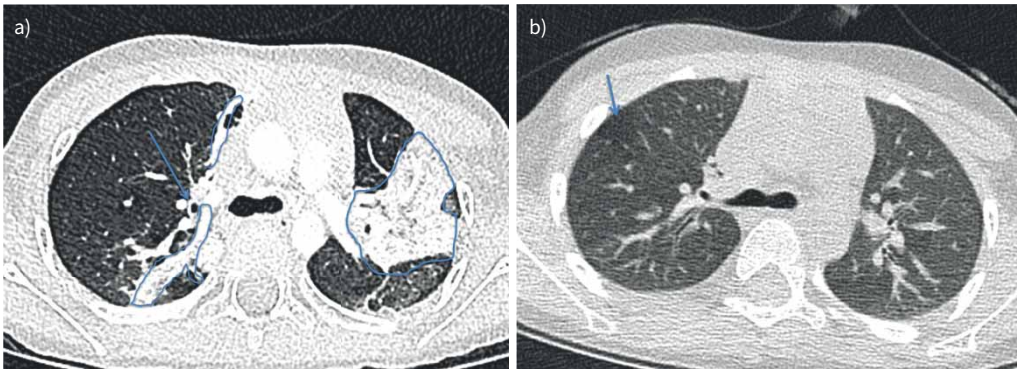

FIGURE 5 a) Initial computed tomography (CT), annotated; b) repeat CT.

Further thoughts

The CT images were imported from a centre with a relatively slow CT scanner and the patient was a typically uncooperative 3-year-old. As such, the examination was performed under general anaesthetic with an endotracheal tube (not shown here, but visible on the planning "scout" image taken before the scan). Figure 5b shows the axial section taken from a repeat examination the very next day, on a state-of-the-art CT scanner capable of freezing respiratory motion even in fast breathing and relatively non-compliant children. It is easy to recognise that the lungs appear well aerated in this image and the large airways are normal in appearance. There is perhaps a very mild area of low attenuation (increased black appearance) within the right upper lobe (marked by an arrow), which could represent some "small airways disease". So why do the lungs look so different only 24 h later?

The answer

Intubation with muscle paralysis results in the rapid appearance of dependant atelectasis mimicking disease and obscuring pulmonary structures. Therefore, where possible, awake, free-breathing CT imaging is far better both for the child and the radiologist. Where general anaesthesia is needed (no matter how good the CT service is, there are always a few cases where this is necessary), some large recruitment breaths to total lung capacity ahead of an inspiratory breath-hold should be requested from the anaesthetist. This is to ensure the lung is adequately inflated at the time of the CT acquisition.

Practice and learning point

This child had two CT scans when one should have sufficed. To avoid this outcome and the consequences from multiple radiation exposures, children should ideally be scanned in centres experienced in paediatric radiology and on the best equipment available.

Case 6

A 4-year-old child recovering on paediatric intensive care unit (PICU) following cardiac surgery (figure 6).

Initial thoughts

This initial chest radiograph demonstrates that the endotracheal (ET) tube is well positioned as are the NG tube, mediastinal and pleural drains, temporary pacing wires and the right atrial line (figure 6a). The heart is very central, but this is a child with congenital heart disease. There is bilateral chest wall soft tissue oedema and the lungs are slightly grey (possibly some mild haemodynamic pulmonary oedema or lung injury, since the child had recently come off cardiopulmonary bypass).

In the subsequent chest radiograph (figure 6b), the ET tube has been removed, as have the drains and pacing leads. The NG tube (marked with an asterisk), peritoneal dialysis catheter (marked with a short arrow) and right atrial line (marked with a long arrow) all remain in place and the lungs look less grey. The soft tissue oedema has also resolved. Now with fewer lines, the dextrocardia is obvious (but note the left-sided stomach gas and the opacification of the left upper quadrant of the abdomen, abdominal situs is solitus as is bronchial situs).

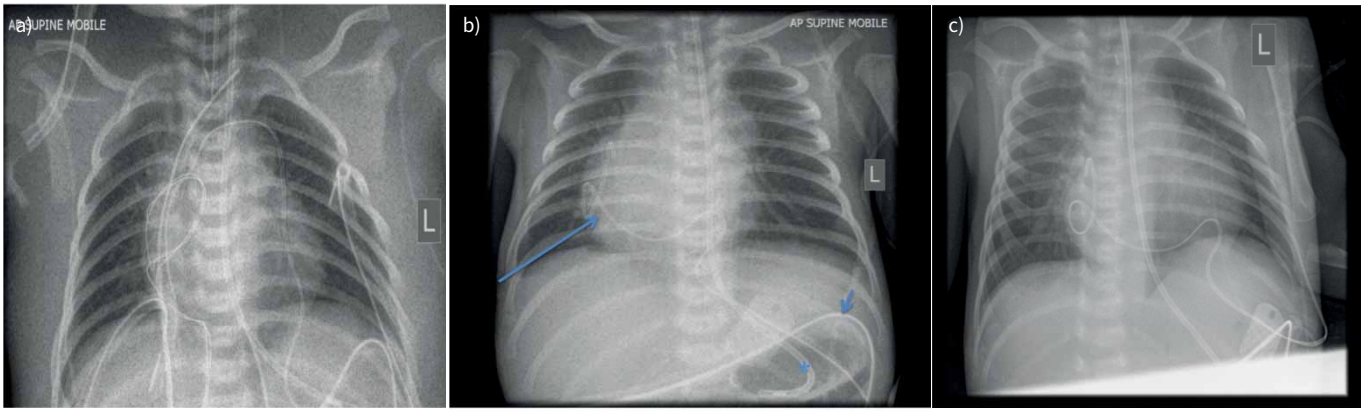

FIGURE 6 a) Chest radiograph; b) repeat chest radiograph; c) further repeat chest radiograph.

In a further repeat chest radiograph the tubes and lines are still well positioned (figure 6c). The lungs are bit more grey in this image, but this could just be because the radiograph is slightly less well penetrated. An initial query is in the perplexing nature of the changing heart positions, dextrocardia doesn't resolve? Furthermore, has the child now developed a relatively large left pleural effusion? Does this indicate the "greyness" of the lungs is actually increasing pulmonary oedema?

The answer

All of these radiographs are of the same infant, each 24 to 48 h apart. The apparent change in position of the heart is purely down to rotation. In older children and adults, we often look at the position of the clavicular heads relative to the spine to judge degree of rotation, but that can be difficult in babies and infants. Look at the shape of the ribs. In the second radiograph (figure 6b) the right ribs are long and relatively straight, the left short and more curled. On the later follow-up radiograph (figure 6c) this appearance is reversed. The longer, straighter ribs indicate that the rotation is closer to the radiographic detector on that side, placed under the infant on PICU. The heart is anterior and the anterior–posterior (AP) projection is exaggerating the effect of rotation on apparent cardiac position. The apparent left pleural effusion (figure 6c) on the last radiograph is in fact the soft tissue of the left arm, which is being held down and slightly across the left chest.

Case 7

A 4-year-old child with difficulty in breathing (figure 7).

Initial thoughts

After a systemic review of the chest radiograph (in figure 7a), you might conclude that there is a pneumothorax on the right, and this would be in keeping with the clinical presentation with of dyspnoea.

The answer

However, follow the apparent lung edge superiorly (figure 7a, b) and you can appreciate it extends well up into the neck and off the top of the image. It is a skin fold. Skin folds can trap air outside of the thorax and create an interface mimicking a pneumothorax. Interpretation is not helped here by rotated and very lordotic projection (the latter resulting in the clavicles being projected well above the thoracic inlet). Could this have been surgical emphysema rather than a skin fold? Well theoretically yes, but it would be unusual for the gas to track in such a straight line. Surgical emphysema often has a more feathered edge as the gas tracks though the soft tissues of the chest wall. The heart is not normal either. This is a child with repaired tetralogy of Fallot, but accurate assessment of the mediastinal structures would require a radiograph with better patient positioning.

For an example of more typical surgical emphysema see figure 7c (patient b for comparison) where there are less focal lucencies in both supraclavicular fossae and the left chest wall (circled). Note also the demonstration of the inferior surface of the thymus in keeping with pneumomediastinum (arrow).

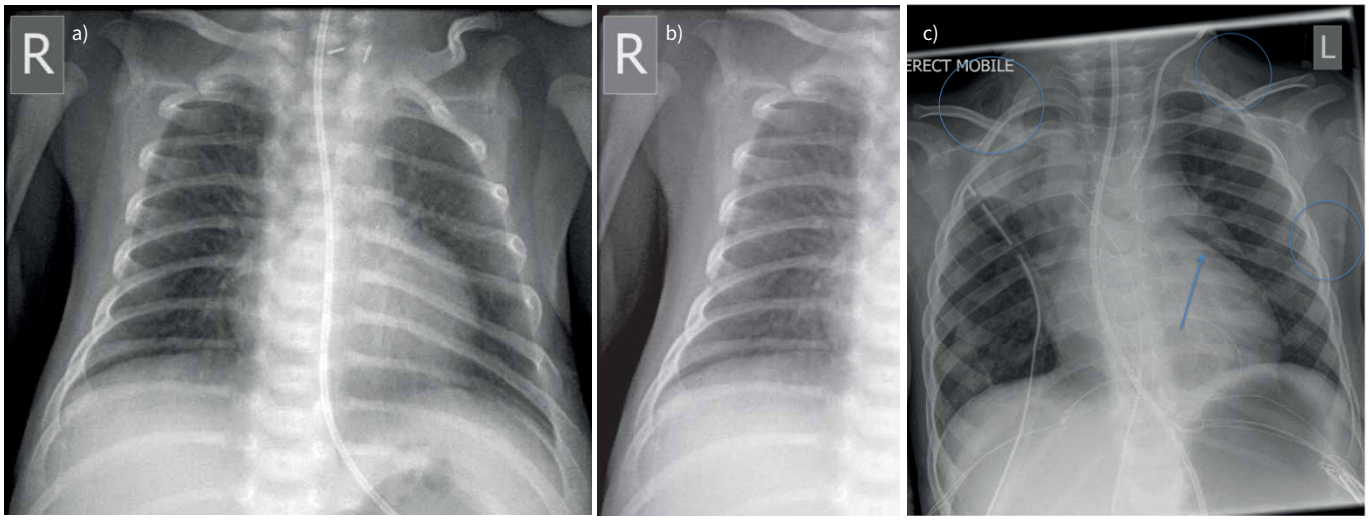

FIGURE 7 a) Initial chest radiograph of patient A; b) focused in review of figure 7a (patient A); c) patient B for comparison.

Case 8

A 2-year-old with proven adenovirus and bronchiolitis transferred to CT from PICU (figure 8).

Initial thoughts

You will recognise that there are bilateral abnormalities on this CT slice with marked bilateral "mosaic attenuation" (outlined in blue), bronchial wall thickening (arrow) and mucus plugging with some right middle lobe atelectasis (asterisk). This appearance is reported to be 100% specific for constrictive obliterative bronchiolitis. Should the physician, therefore, start having difficult discussions with the family about a life of follow-up appointments, complicated prognosis and the possible need for lung transplantation in the future?

The answer

The initial thoughts on these imaging findings are correct, but the context is important here. The mixed areas of grey and black lung are termed "mosaic attenuation". In this case there is a very clear reduction in size and number of blood vessels in the black-appearing lung, implying that it is the black lung that is abnormal (as opposed to the grey lung which would be termed "ground glass" in appearance if the blood vessels were uniform in appearance across both the grey and black regions). Mosaic attenuation is seen both in small airways disease (where the abnormal lung is black as there is simultaneously too much gas and too little perfusion, as blood is shunted to normally ventilated lung elsewhere) and in disordered pulmonary perfusion (where regional perfusion may reduce distal to an embolus or in a region of abnormal vascularity, as seen in some congenital heart diseases and other rarer pathologies). The presence of large airways disease in this particular case (the bronchial dilatation, thickening and plugging) pushes us very much toward this being a combined small and large airways pathology. In the right clinical context, this is indeed an appearance almost pathognomonic of constrictive obliterative bronchiolitis, but is this the right clinical situation in this particular case? Read on.

Explanation continued

The original imaging was imported for review at a specialty multidisciplinary team meeting a few years later (figure 9). Hindsight is a great gift and the child had been doing very well "given the severity of disease on CT". A repeat CT was organised to clarify the diagnosis and guide the need for any future treatment. The lungs are now normal in appearance with no residual mosaic attenuation and the bronchial dilatation, thickening and plugging has completely resolved. This child does not have constrictive obliterative bronchiolitis.

The key realisation in this case was that the initial CT was performed acutely, during an active viral infection with ongoing acute bronchiolitis. The CT (and indeed radiographic) appearance of acute bronchiolitis can be identical to that of obliterative bronchiolitis. All the images tell you is that at the time of imaging, there are areas of lung ventilated by partially obstructed airways with a long time constant.

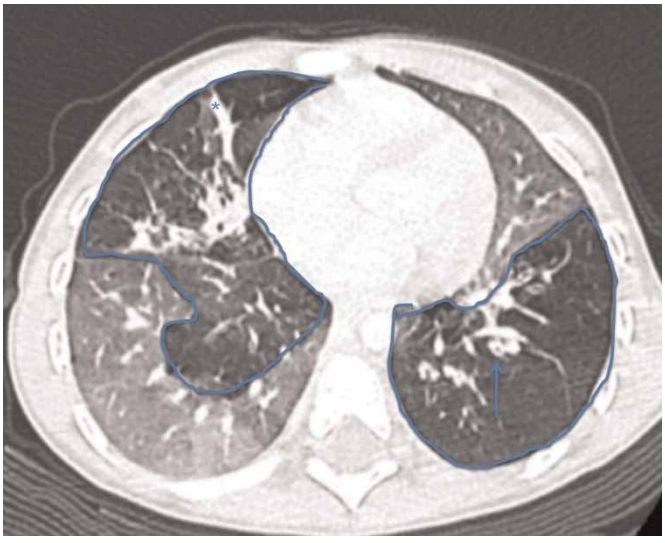

FIGURE 8 Initial computed tomography.

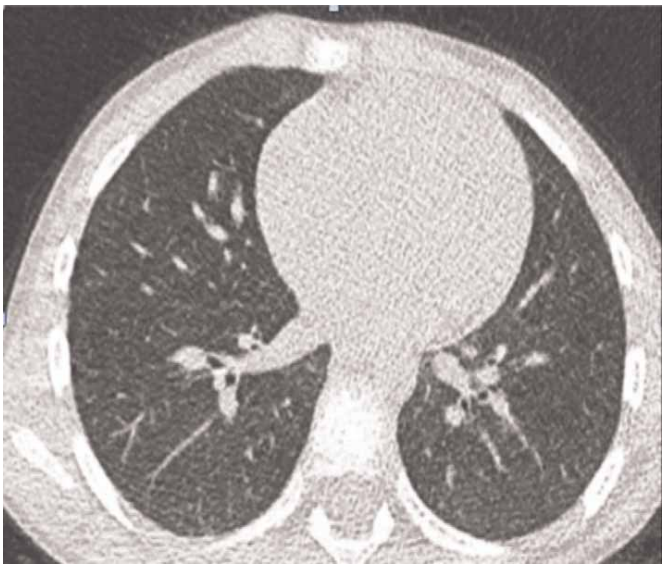

FIGURE 9 Computed tomography 6 years after initial presentation.

They do not tell you the cause of the partial obstruction nor whether it is reversible. If imaging is performed with the express question "is this post-infective constrictive obliterative bronchiolitis?" then ensuring imaging is performed as far after the acute event as is feasible is critical to avoiding over-diagnosis and the inappropriate labelling of imaging features as irreversible disease. This is just as true in the setting of the reversible airway dilatation occasionally encountered in acute infection, where it may not necessarily represent irreversible "bronchiectasis" and can be completely reversed with appropriate treatment. The reminder that nothing is ever "100%" in medicine still stands true.

A matter of time

Case 9

A 1-year-old child attending follow-up having been recently discharged following a viral bronchiolitis (admitted for support, but never ventilated) (figure 10).

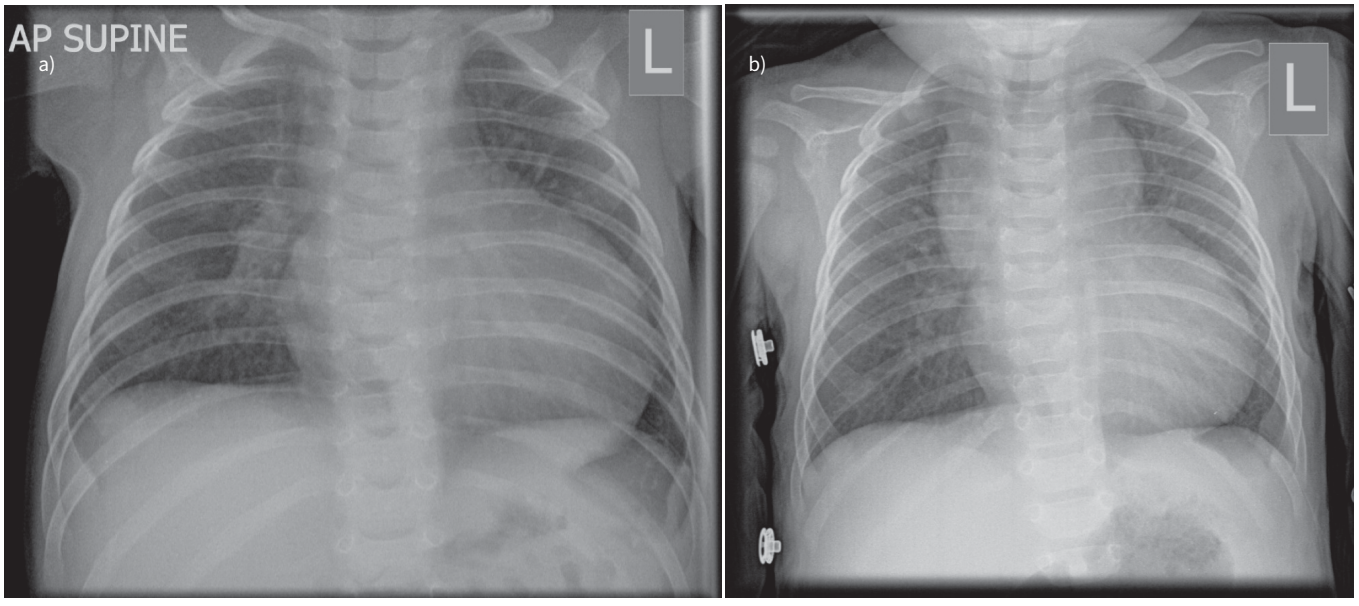

FIGURE 10 a) Chest radiograph pre-discharge; b) follow up in clinic 6 weeks later.

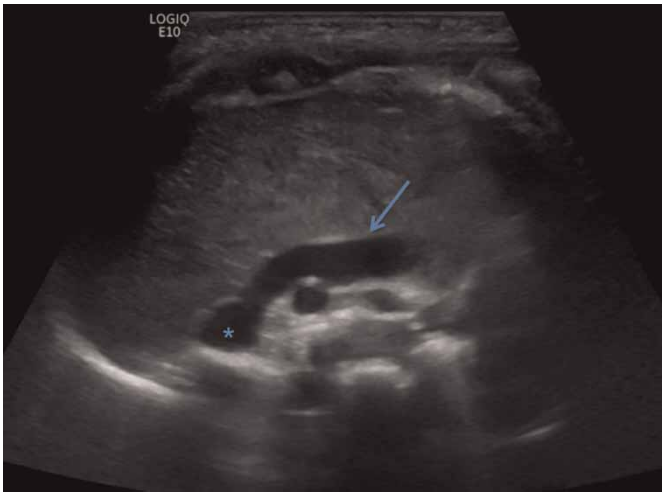

FIGURE 11 Ultrasound imaging of the normal appearing thymus with no cysts or vascular compression to suggest thymic pathology. The asterisk indicates the superior vena cava, the arrow the left brachiocephalic vein.

Initial thoughts

A chest radiograph during an acute episode of bronchiolitis is likely to demonstrate a degree of hyperinflation. In figure 10a, the lungs were still mildly hyperinflated pre-discharge, flattening both hemidiaphragms, and the heart looks enlarged. This could perhaps be attributed to an inadequate breath in. On the follow-up film (figure 10b), the lungs are more hyperinflated still, but is there now also a mediastinal mass pushing the trachea to the right?

The answer

The initial pre-discharge radiograph is a poor inspiration, but there is indeed some residual hyperinflation (the right diaphragm is quite flat despite the expiratory nature of the image) and the heart is enlarged (this child has a known dilated cardiomyopathy). The clinic follow-up image does indeed show persistent hyperinflation with flattening of both hemidiaphragms. Depending on their clinical trajectory this may warrant further investigation (for example, is there post-infective constrictive obliterative bronchiolitis?). The cause of the mediastinal mass should be obvious. The child is recovering from an acute illness and this is the time when there may be so-called thymic rebound, of which this is a particularly good example. If in doubt, ultrasound is a useful imaging modality as normal thymus has a typical and very specific appearance (figure 11). Furthermore, the slight tracheal deviation to the right is at the level of the left-sided aortic arch and is a normal finding (figure 10b). This deviation is often exaggerated on expiration, particularly in infants. The degree of hyperinflation of both lungs is now considerably worse and does indeed warrant further investigation.

Practice point

Do not just see the mediastinum and think “that’s a great case of thymic rebound”; don’t forget to look at the rest of the image.

Conclusion

Radiography is a difficult job and not every imaging study is perfectly performed. We have extra problems within paediatrics with patients who love, deliberately or otherwise, to try to confuse us by adding objects (dummies, toys, hair accessories, hands, *etc*.) to our images, many of which can be confused with a genuine pathology. Imaging appearances are also influenced by factors within our own control (the use of intubation for CT imaging, the timing of imaging studies relative to acute infections, *etc*.). As such, paediatric chest imaging is a truly multidisciplinary task and one best performed as a team. Respiratory and general paediatricians of all levels of experience need to get to know their radiologists, they will have seen a lot of imaging and will be acutely aware of the artefacts and confounding features shown above and many more. Radiologists, get to know your paediatricians, they will have seen many presentations of many respiratory pathologies and a good number of presentations of non-respiratory pathology (and indeed non-pathology) presenting as respiratory pathology. As for radiographers, they know you all and are the most critical asset of any imaging department no matter how big or small that department may be. Work as

a team, discuss cases as a team and consider the whole presentation and imaging process and hopefully you will avoid the traps above.

We hope that in reading this you learned something useful to your everyday practice and that if not, you at least enjoyed a review full of interesting images that, for the most part, all turned out to be normal!

In conclusion, seeing should be kept separate from believing, and conventional beliefs may impede diagnosis. As Sherlock Holmes proved, you do not see what you fail to look for.

> "It was invisible, buried in the mud. I only saw it because I looked for it" [11]

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