

DUAL ENERGY SUBTRACTION RADIOLOGY



“Wheatfield with Crows”, Oil on canvas, Vincent Van Gogh, 1890, Van Gogh Museum, Amsterdam.

“So why are the landscapes, our mindscapes?”

There're anything but deranged. There unflinching, tumultuous, heroic and completely new. And here's the most startling of them all, “Wheatfield with Crows”, not for what it's supposed to say about van Gogh's frailty, because I don't think that the artist that painted this was frail at all, but for what it says about the conventions of art. It shows Vincent in total command, never fiercer in his contempt for the rules in his headlong rush to junk the entire history of landscape painting - starting with perspective. Its whole point had been to create an illusion of deep space so that the eye could confidently wander through to a distant horizon. But here perspective is reversed. It's a road that goes nowhere and the two flanking paths just seem to rise up vertically through the picture like flapping wings. And what are those green borders? Grass? Hedges? The corner of a tree? All our signals, our assumptions about how to read visual signs have been wickedly scrambled. So what are we looking at? Suffocation sure. But elation too. Those crows might be coming at us, but equally they may be flying away - demons gone, as we sink into a total immersion in the power of nature and into a massive wall of writhing brilliant

paint, in which the colour itself seems to tremble and pulse and sway. And it's with this independent life of formed blocks of colour that Vincent van Gogh creates modern art.

This physical feeling, simultaneously thrilling and terrifying of being swallowed alive in paint, lies at the heart of so much modern art. And it was what Vincent had been yearning to realize ever since he picked up a brush on the dark moors of north Holland. The pilgrim had gone the distance. I don't think there's the slightest possibility that accomplishing this revolution could have been a moment of suicidal despair for Vincent van Gogh. In his art he'd never been more visionary, never more brilliant - but not in his life.

In his last letter to Theo, Vincent wrote of how not managing to have a child, his paintings were his progeny. But he did have a child of course - expressionism - and many many heirs - Kokoschka, de Kooning, Howard Hodgkin, Jackson Pollock. But there's something about van Gogh's legacy which is much more important than his fathering this or that "ism" of modern art. Vincent's passionate belief was that people wouldn't just see his pictures but feel the rush of life in them, that by the force of his brush and the dazzlement of his colour they'd experience those fields, those faces, those flowers in ways nothing more polite or literal could ever possibly convey. His art would reclaim what had once belonged to religion, consolation for our mortality through the relish of the gift of life. It wasn't the art crowd he was after. What he wanted was to open the eyes and the hearts of everyone who saw his paintings - well he got what he wanted"

Simon Schama, "The Power of Art", BBC Television, 2010.

What makes a painting great? Pure aesthetic beauty? - sheer technical brilliance? - historical or cultural priceless? - the ability to stimulate intense emotion or feelings that transcend time and space? - or perhaps simply being the very first in a stunning innovation, something that completely and forever alters perceptions? Oceans of ink have been spilt over the centuries pondering just this issue. The magisterial Art commentator Simon Schama would argue that Vincent van Gogh's "Wheat Field with Crows", is one of humanities' great works of Art. Great in the category of forever altering our perception and our appreciation of what Art can bring into our lives.

*In the decades previous to Van Gogh's work, the Impressionists had achieved this ideal. A new Art form of brilliant or subtle lighting capturing the fleeting moment of everyday life - leaving us not with some grandiose or idealist "lesson" to be learnt - but rather a real human experience. Van Gogh is difficult to classify as many Art commentators and historians love to do - but one label - if there must be one at all - rests fairly well. Vincent was the greatest "Post-impressionist"; and some commentators would argue that perhaps the greatest Post-impressionist work of all is "Wheatfield with Crows". Vincent appreciated the works of the Impressionists but only to a certain point. He could brilliantly produce these types of works himself; however he felt they did not go far enough. In his biographers' words (Naifeh and Smith) "In Vincent's reality, (images had to have significant meaning); Any image that did not reach **beyond** its immediate subject, he dismissed as a mere "impression" - an ephemeral artefact, like a sketch, useful only to the artist in his continuing quest for something more, "noble and serious". To achieve significance, an image had to strip away the specifics of the observed world and*

“concentrate on what makes us sit up and think”. “An image that can rise up above nature”, he said, “is the highest thing in Art”. He wrote that Art should be “personal and intimate”, and concern itself “with what touches us as human beings”. He pledged to seek images, “that almost everybody will understand” and to simplify each image “to the essentials, with a deliberate disregard of those details that do not belong”.

Vincent painted in an impressionist style, but in one far more powerfully portraying feeling and emotion over and above “mere impressions”. With his brilliant, vibrating, writhing slabs of paint so full of passion and energy he painted, as Schama writes “from inside his head”. It is this emotional power that emanates from his works; that was novel; that was “Post Impressionist”; that made him great - in Schama’s view, ushering in truly modern Art; the father of the great Twentieth century Expressionists, but more than that. As Schama writes: “Vincent’s passionate belief was that people wouldn’t just see his pictures but feel the rush of life in them, that by the force of his brush and the dazzlement of his colour they’d experience those fields, those faces, those flowers in ways nothing more polite or literal could ever possibly convey. His art would reclaim what had once belonged to religion, consolation for our mortality through the relish of the gift of life. It wasn’t the art crowd he was after. What he wanted was to open the eyes and the hearts of everyone who saw his paintings - well he got what he wanted”

Yes he certainly did achieve what he wanted in his Art; but tragically he did not live to see this for himself. He committed suicide just weeks after he had created “Wheatfield with Crows”. He died destitute; desperately lonely; friendless apart his from his long suffering brother, Theo; wracked with mental illness which today would perhaps be diagnosed as severe bipolar affective disorder; unable to sell virtually any of his work, and completely unknown to the world. Before he died he wrote to his brother:

“Theo...What am I, in the eyes of most people? A non-entity? An eccentric? An unpleasant person? Somebody who has no position in society and never will. In short the lowest of the low. All right then, well even if it were all absolutely true, then one day I should like to show by my work what such a non-entity, such a nobody, has in his heart”.

With a handshake, ever yours, Vincent.

Today Vincent’s major works, on the rare occasion that one actually comes onto the market, sell for well in excess of 100 million US dollars.

The computerized digital age has created a revolution in a vast array of technologies, including most impressively that of so-called “plain” radiography. Like the impressionist movement in Art, when digital radiology was introduced, it too was scoffed at and a little slow to be accepted. Now of course this new Art form is here to stay. But the technology continues to evolve. From mere “impressions” we now enter the next phase of this technology; a “Post Impressionist” digital age that produces images that can convey so much more meaning to us than the mere “fleeting moment”. This Post Impressionist revolution comes to us in the form of “Dual Energy Subtraction Radiology”.

DUAL ENERGY SUBTRACTION RADIOLOGY

Introduction

Dual Energy Subtraction Radiology (DESR) is a novel computerized digital radiological imaging technique that has a range of advantages over conventional radiography that facilitate image interpretation.

Its drawback over conventional radiology is the increased radiation dose required for the technique.

The technique is particularly useful in regard to imaging the chest, but as further experience is gained with the technique, further indications are likely to emerge.

Physics

Dual-energy subtraction takes advantage of differences in the degree to which body tissues attenuate low and high energy (measured in kilo electron volts) photons.

These differences are used to generate tissue-selective images.

Bone, because it contains calcium, has a higher attenuation coefficient (i.e. absorbs more photons) at lower photon and beam energy. This effect is more pronounced for calcium-containing tissues than for soft tissues, so that structures that contain calcium (including bone) can be removed from images, leaving soft tissues and lung.

Two types of dual-energy systems are available: a **single-exposure system** and a **dual-exposure system**.

In **single-exposure systems**, one radiograph is obtained by exposing two storage phosphor plates separated by a copper filter. The front plate receives the whole, unfractionated energy beam, which produces the standard image. This plate and the copper filter select out lower - energy photons such that the back plate receives mostly higher-energy photons. One weighted subtraction is used to produce a bone selective image, whereas a different weighted subtraction is used to produce a soft tissue-selective image. One disadvantage of a single - exposure system is the lower signal-to-noise ratio of the tissue-selective subtraction image.

In **dual-exposure systems**, two sequential radiographs are obtained at 60 and 120 kV, respectively. The higher - kilovolt exposure is used to produce the standard image. There is a 200-millisecond delay between the two exposures. This delay can create misregistration artefacts on the subtracted images due to slight offsets in the alignment of body structures caused by cardiac, respiratory, bowel, and patient motion. However, dual-exposure systems produce tissue-selective subtraction images with a better signal-to-noise ratio than those produced with single-exposure systems.

Types of Images

Dual-energy subtraction chest images are displayed in a “trio” format that includes a standard unsubtracted image, a soft tissue–selective image, and a bone-selective image.

These three images may be viewed in a scrollable stack or side by side for simultaneous comparison, as below:

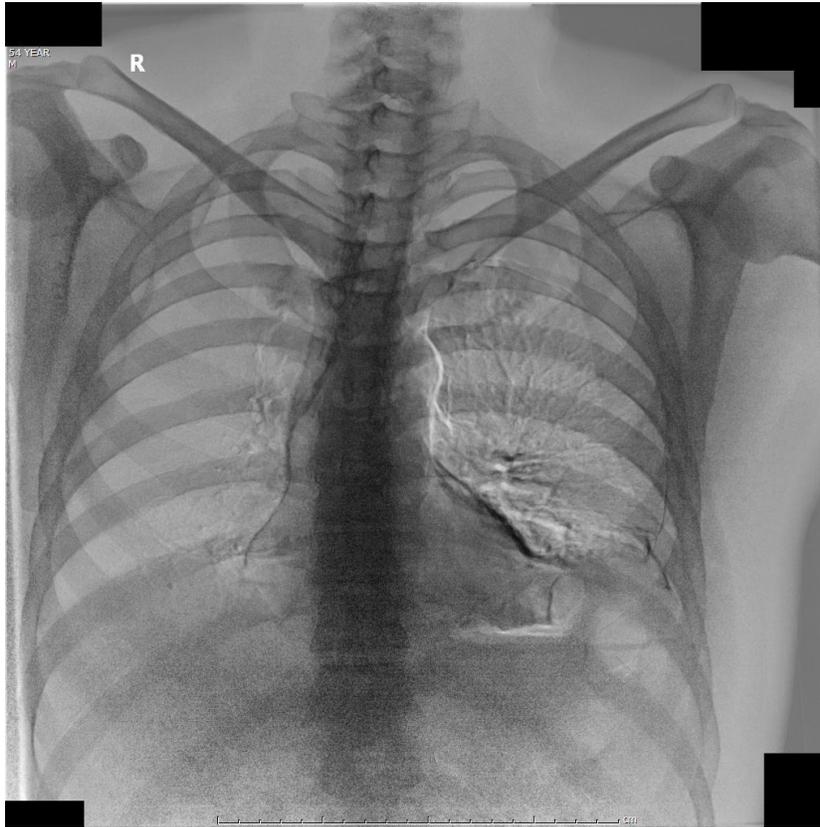


Above Left: Normal unsubtracted chest radiograph, of a 54 year old male who had fallen from a ladder.

There is a left sided pneumothorax, at the level of the 5th rib - but this is difficult to detect.

Above Right: A bone subtracted, soft tissue image, (low kV) very clearly shows the pneumothorax, without the need for additional expiratory films.

Below is a bone (i.e. high kV - Soft tissue subtracted) image, giving far better bony definition. No fractures are seen.



Soft tissue subtracted, bone image of the above patient.

Advantages

Dual Energy Subtraction Radiology (DESR) is a novel computerized digital radiological imaging technique that has a range of advantages over conventional radiography that facilitate image interpretation.

Dual-energy subtraction imaging allows better visualization of a variety of entities, including nodules, bone lesions, vascular disease, pleural disease, mediastinal and hilar masses, tracheal and airway abnormalities, complex chest disease, and indwelling devices.

Disadvantages

These include:

- DESR radiology requires higher radiation dosing than conventional radiography.
- **Misregistration artefacts may occur on dual-energy subtraction images that are obtained with a dual exposure technique.**

The 200-millisecond delay between the two exposures can cause artefacts on the subtracted images due to slight offsets in the alignment of body structures caused by various kinds of motion.

These artefacts are seen as **black or white lines** along the diaphragm, cardiac silhouette, aortic arch, bowel, and pulmonary arteries, as well as along indwelling devices such as pacemaker wires (see appendix 1 below). These artefact lines can be seen on one or both subtraction images but are usually most conspicuous on the bone-selective image.

- Patients need to be still during imaging process to reduce motion artefact, and so an increased degree of compliance is necessary.

Indications

DESR has many advantages in regard to imaging of the **chest** in particular.

In regard to important indication within the Emergency Department setting, these include:

1. Clearer delineation of rib lesions:
 - **Fractures**
 - **Metastases**, including multiple myeloma.
2. Other bony lesions:

DESR appears to be useful for:

- Scaphoid fractures
 - ♥ Radiation exposure is minimized somewhat by removing the need for the *multiple* standard views required by conventional radiology.
 - Neck of femur or pubic rami fractures
3. Pneumothorax:
 - Radiation exposure is minimized by eliminating the requirement for an additional forced expiratory view routinely used for the detection of more minor pneumothoraces
 - A routine **inspiratory** view (the standard CXR view) only is required
 4. The detection of tracheal or bronchial narrowing
 5. Endotracheal or endobronchial masses

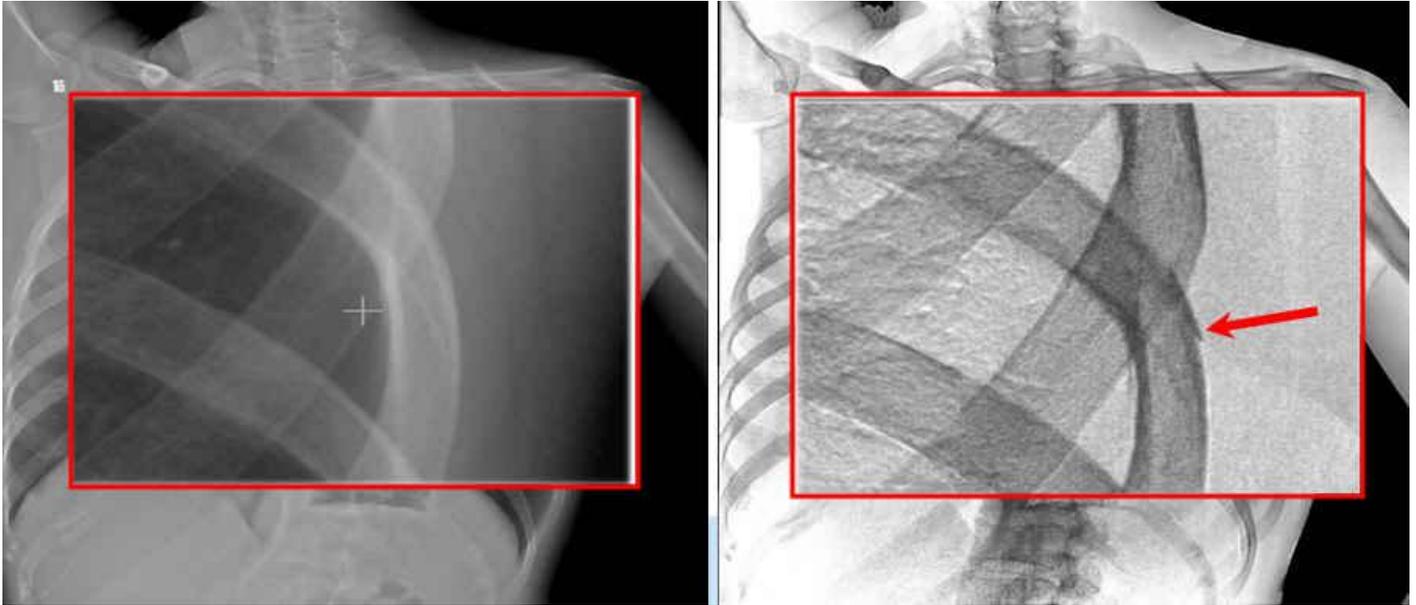
6. Delineation of foreign bodies aspirated into the trachea or bronchi
7. The localization of indwelling devices such as stents and catheters
 - Dual-energy subtraction improves the visualization of foreign matter. Often, indwelling devices and foreign bodies are best seen on bone-selective images; these entities include breast implants, surgical clips, catheters and catheter fragments, and vascular stents (including coronary artery stents).

Further applications include:

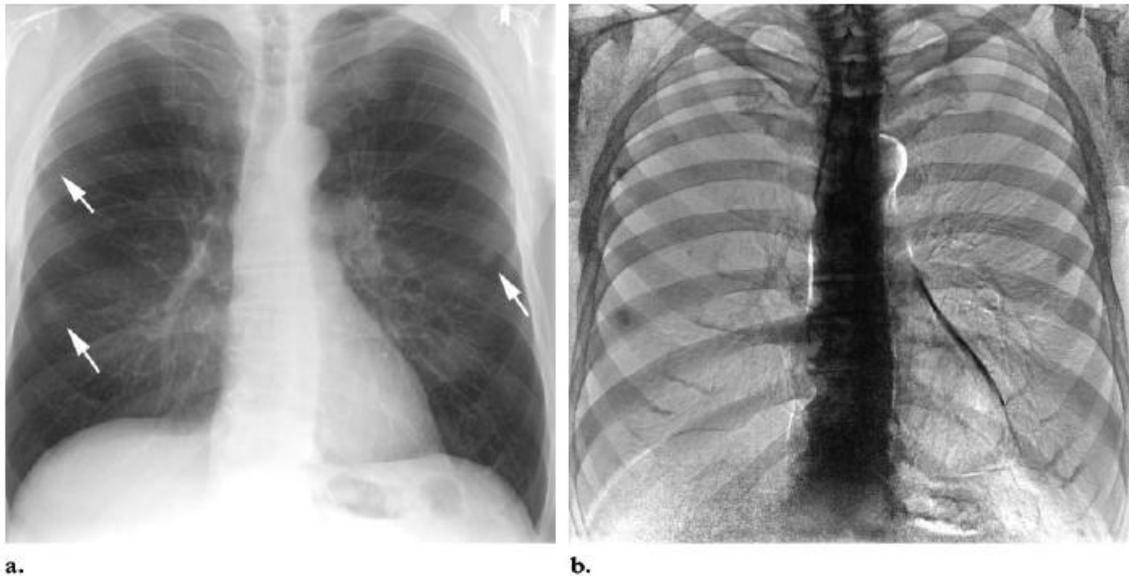
8. Pulmonary nodules:
 - It more clearly depicts **calcification** in soft tissue subtracted images.

When soft tissue is subtracted, it greatly aids in the characterization of pulmonary nodular lesions, which may not even be apparent on conventional images.
9. It is helpful in the recognition and interpretation of hilar and mediastinal masses.
10. It is helpful in the recognition and interpretation of pleural and chest wall lesions.
11. Some forms of vascular disease, (pathological calcification).
12. Foreign bodies:
 - Soft tissue subtracted images may have a role in the clearer delineation of foreign bodies.

Appendix 1



Left: Conventional rib view radiograph. Right: DESR, Bone view, shows a fracture, not apparent on the conventional view.



Standard unsubtracted image obtained in a 55 year old man with prostate cancer and possible lung nodules. The image demonstrates what appear to be nodular opacities (arrows) in the lungs. (b) Bone-selective image reveals that the multiple “lung nodules” seen in (a) represent bone metastases. No lung metastases are present. Note the misregistration artefacts due to cardiac pulsation and motion along the border of the left side of the heart (black streak) and along the aorta (white streak). This type of artefact may be seen on dual-energy subtracted images that are obtained with a dual-exposure technique.¹

References

1. Janet E. Kuhlman, et al. Dual-Energy Subtraction Chest Radiography: What to Look for beyond Calcified Nodules. Radiographics vol 26. No. 1, Jan-Feb 2006.

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