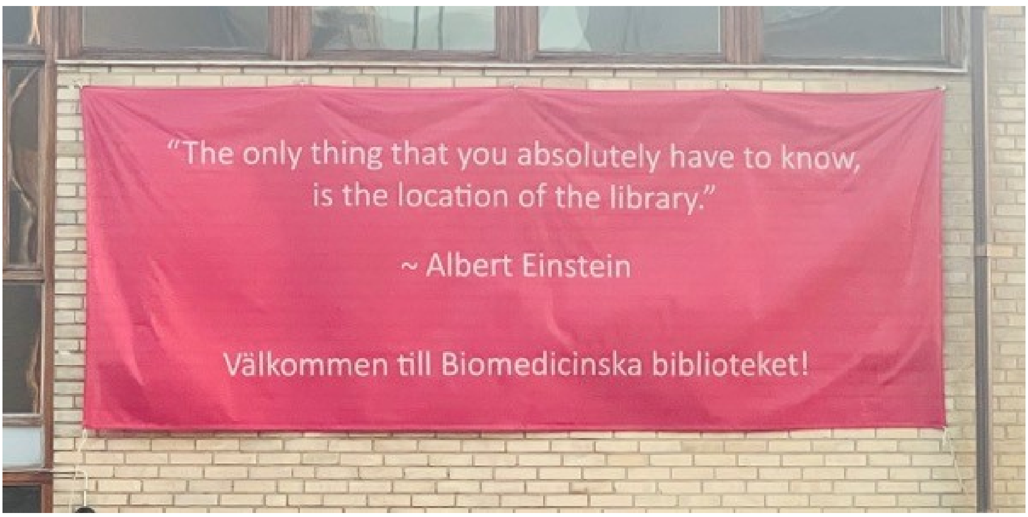
The Invisible Light

The Journal
of
The British Society for the History of Radiology



Number 57, November 2025
ISSN 1479-6945 (Print)
ISSN 1479-6953 (Online)
www.bshr.org.uk

Contents.

Editorial:

The world of radiology and medical history has been busy since our last journal. It's important that radiology history is well represented within the medical history community – we are part of medical, science and social history. It's also important that radiological history is well represent within local history. If you have a local history society near you then consider getting involved. You can present the history of your hospital and of its radiological services. I have found those involved in local history to be very friendly, and local medical history is always welcomed. I am on the committee of my local history society, the Bromley Borough Local History Society.

So, month by month, this is what has happened in the radiology history world:

June:

- The premier UK radiology event is UKIO **(UK Imaging and Oncology Congress) 2025: Community & Consciousness: One Health.** This was held in the ACC Liverpool in Kings Dock. There were an excellent selection of proffered papers and the history session was well attended. The BSHR again had a stand and we had a good number of visitors. We always welcome help looking after the stand. We had well attended sessions of 'Education on the Stand'. Again, if you have an idea for an 'Education on the Stand' then please do contact us. Also consider submitting a paper. The theme of UKIO 2026 is 'Putting humanity at the centre of healthcare In the age of the machine,' and abstracts need to be submitted by 9 February.

September:

- The **31st BSHM (British Society for the History of Medicine) Congress 2025** was held in Leeds. The BSHR is a member of British Society for the History of Medicine, and our members are encouraged to attend and to present a paper. The congresses are always interesting. The next congress is in 2027 with the venue as yet undecided. We need more radiology themed papers! In 2026 we will have the on-line Poynter Lecture, and so there is plenty of time to prepare a paper. As members of BSHR we are eligible for free membership of the BSHM as a member of an affiliated society. You may register at https://bshm.org.uk/membership/register-bshm-member-affiliated-organisation/ . The inaugural John Blair Trust Lecture by Iain Macintyre, held at the BSHM Congress, was recorded and the direct link to the recording of Iain Macintyre's Lecture is https://youtu.be/1B8J3WydVpE . We thank the Past BSHM President, Edward Wawrzynczak, and welcome the new President, Hilary Morris.

- Also, in September the **HMES, The Historical Medical Equipment Society** meeting took place at the Creative Health and Heritage Centre at Glenfield Hospital in Leicester. There were several radiology themed presentations. The Historical Medical Equipment Society is interested in physical medical equipment, of which radiology is entirely dependent. The 2026 meeting will again be in the Karl Storz Endoscopy: Endoscopic Training Centre in Slough. Do consider showing and talking about a piece of equipment that you find interesting. The meeting is worth attending simply to visit the Karl Storz Endoscopy: Endoscopic Training Centre with its fascinating collection of old and contemporary endoscopic apparatus. I will put further details in our next journal.

October:

- The **14th Symposium of ISHRAD, the International Society for the History of Radiology**, took place in Sahlgrenska Akademin, Medicinaregatan in Gothenburg, Sweden. The meeting was good with many excellent presentations. This should be the major meeting for those interested in the history of radiology, and it's a shame that more didn't attend. The 2026 meeting is planned for 10 October. It will be organised by the Department of Radiology, Medical faculty at University of Reszów (Polradiologia Viva Foundation) in Poland. Rzeszów is the largest city in southeastern Poland. It is located on both sides of the Wisłok River in the heartland of the Sandomierz Basin. Please try to attend and submit a paper. The 1st Symposium of ISHRAD took place in London, and it's time that the UK hosted another.

November:

- The **BSHR 2025 On-Line Lecture** was given by Iwan Morus: "Making up the Future: Nikola Tesla's Body Electric." Iwan Rhys Morus is Professor of History at Aberystwyth University. He has published widely on the history of science, with titles including 'Michael Faraday and the Electrical Century' (Icon, 2017), 'Nikola Tesla and the Electrical Future' (Icon, 2019) and the 'Oxford Illustrated History of Science'.
- The **BIR (British Institute of Radiology) Annual Congress 2025 Routine to Innovation, Shaping the Future**, took place at the Park Plaza Victoria in London. Whilst the congress concentrates on contemporary practice there is an opportunity to present electronic posters with an historical theme, so consider offering a poster next year.

The Clifton Prize Essay has proven to be popular. The quality of essays in 2025 remained hight. The Winning Entry by Katharine Kenny (now Katharine Thomson), 'The First Thyroid Radionuclide Therapy Patient? A Mystery in Time and Music', is reproduced below. The runner-up essay will be published next year. Please encourage submissions for the 2006 Clifton Prize Essay.

Thanks to Edwin Aird for his interesting paper on bone mineral measurement. So please enjoy this issue, consider submitting a paper.

Adrian Thomas

adrian.thomas@btinternet.com

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"The only thing that you absolutely have to know, is the location of the library."
~ Albert Einstein
Välkommen till Biomedicinska biblioteket!

This comment by Uncle Albert was seen opposite the entrance to the building where the ISHRAD meeting was held and is reproduced on the front cover. The location of the library is now an interesting concept in this time of virtual libraries; however real physical books can never be replaced.

British Society for the History of Radiology.

The BSHR 2026 Annual Lecture will be given at 7pm on Monday 2nd February, at Governors Hall, St Thomas's Hospital, London SE1.

"A personal History of Radiology from Röntgen to the Modern Digital Era & AI. What can we learn from the pioneers?"

by Dr Arpan K Banerjee, MB, BS (Lond.), FRCP, FRCR, FBIR, Chair ISHRAD (International Society for the History of Radiology).

Arpan Banerjee has been researching and writing about radiology history for over 30 years, and has published over a hundred papers and essays and several books on aspects of radiology and medical history. He is the author of 'Radiology of AIDS' (1993), Radiology Made Easy (1999, 2006), and co-author of the books 'Classic papers in Modern Diagnostic Radiology' (Springer 2004) and 'The History of Radiology' (OUP 2013). His latest project was co-editing and contributing to the book 'Pioneers in Radiology Worldwide at the time of Wilhelm Rontgen' published in Paris in 2024.

In this talk he will review the lives and contributions of the early radiology pioneers from Rontgen, Madame Curie and others and also cover the development of early ultrasound, CT, MRI and interventional radiology and AI. The talk will provide a historical overview of some of the key developments in radiology throughout the 20th century and the pioneers involved in these developments and will also remind us of what the lives of these pioneers can teach us in our current era.

Entry is free but for catering purposes please email Dr Arpan Banerjee by 29 January 2026 at arpankb007@gmail.com to attend the lecture.

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I Sing the Body Electric
by Walt Whitman.

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I sing the body electric,
The armies of those I love engirth me and I engirth them,
They will not let me off till I go with them, respond to them,
And discorrupt them, and charge them full with the charge of the soul.

Was it doubted that those who corrupt their own bodies conceal themselves?
And if those who defile the living are as bad as they who defile the dead?
And if the body does not do fully as much as the soul?
And if the body were not the soul, what is the soul?

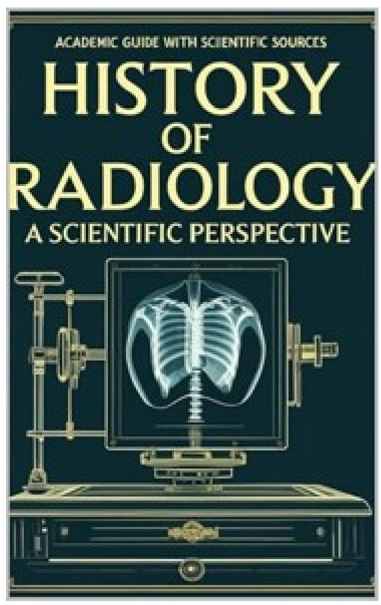
"I Sing the Body Electric" is a poem by Walt Whitman from his 1855 collection ‘Leaves of Grass’. The poem is divided into nine sections, each celebrating a different aspect of human physicality. The first section is reproduced.

New Books:

History of Radiology: A Scientific Perspective: Academic Guide with Scientific Sources (Radiology Now) Kindle Edition

- ASIN: B0FBZ7BV1K
- Publisher: Lumen Books
- Publication date: 3 Jun. 2025

by Eddie Vrundt (Author)



The blurb tells us that radiology plays a crucial role in modern medicine, allowing healthcare professionals to diagnose and treat diseases more effectively. Radiology therefore represents one of the most significant revolutions in modern medicine, fundamentally transforming medical diagnosis since its accidental discovery in 1895. This academic guide examines the historical milestones of radiology through a scientific perspective, based on international academic literature.

The author tells us that the development of radiology can be divided into five distinct periods: the initial discovery (1895-1900), early clinical developments (1900-1920), the contrast media era (1920-1950), the digital revolution (1950- 1990), and the modern era (1990-present).

The evolution of medical imaging has not only revolutionized diagnostic medicine but has also contributed significantly to therapeutic interventions, disease prevention, and medical research. From Röntgen's first X-ray image to contemporary artificial intelligence applications, radiology has consistently pushed the boundaries of medical science.

This eBook, "History of Radiology: A Scientific Perspective", 'offers a comprehensive overview of the evolution of this fascinating discipline, from its origins to the latest advancements'.

The book is only available on Kindle and the cost is modest at £2.24. I can find no reference to Eddie Vrundt apart from as the author of this book. If anyone has any information as to his identity, I would be most interested to know. This book is part of a four-book series entitled 'Radiology Now'. The books in the series are:

1. History of Radiology: A Scientific Perspective: Academic Guide with Scientific Sources (Radiology Now) Kindle Edition, £2.24.
2. Manual of Contrast Radiographic Examinations: Standardized Protocols, Patient Preparation, and Imaging Techniques for Diagnostic (Radiology Now) Kindle Edition, £2.00.
3. Radiant Safeguards: Ensuring Safety in Industrial Radiography: A Comprehensive Guide to Protecting Personnel and the Public from Ionizing Radiation (Radiology Now) Kindle Edition, £2.98.
4. Understanding Radiation: Biological Effects and Environmental Impact: Unveiling the Invisible: A Comprehensive Guide for Students and Professionals (Radiology Now) Kindle Edition, £2.23.

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The Clifton Prize Essay 2024: The Winning Entry.

The First Thyroid Radionuclide Therapy Patient? A Mystery in Time and Music

Katharine Thomson

Mention radionuclide therapy and chances are that, if you think of anything at all, you will think of radioactive treatment of the thyroid. If you are in the Radiology world you may be aware of iodine-131, used to treat thyroid cancer or overactive thyroids. You may have seen Nuclear Medicine scans with the thyroid gland bright like a butterfly, or witnessed elaborate precautions taken to prepare treatment isolation rooms. For trainee physicists this is often the first radionuclide therapy (RNT) that they see as they hover awkwardly in the background.

If you are not in the Radiology world, this is still the RNT that you are most likely to come across. In 2021 (the most recent year for which UK data is available), there were nearly 1600 radioactive treatments of non-cancerous thyroid conditions such as Graves' disease (of which more later) [1]. It is also the one that has been going the longest, a fact with which I try to reassure anxious patients. Its origins date back more than a century, with the current form of iodine-131 taken as a pill developing around the 1940s. There is also a rumour, which we will investigate, that the very first patient was none other than Herbert Howells, one of the most famous English composers of the 20th century. This fact I rarely mention to patients, other than the very occasional one who mentions music when we discuss the activities to be put on hold during their post-treatment restriction period.

First things first: the thyroid is a butterfly-shaped gland in the neck. Part of the endocrine system, it plays a key role in hormone production. The main effect of the thyroid hormones is to increase the basal metabolic rate, which increases pulse rate and body temperature and activates the nervous system. Thyroid hormones require iodine for their production, and are released in response to thyroid stimulating hormone (TSH), itself released by the pituitary gland [2].

Thyroid conditions include underactivity (hypothyroidism) and overactivity (hyperthyroidism or thyrotoxicosis); of the latter, the majority of patients have Graves' disease [3]. This is an autoimmune condition, with an incidence of around 0.2% in men and 2% in women, in which the thyroid produces an excess of hormones. Symptoms include heart palpitations, sweating, exhaustion, nervousness, weight loss, enlarged thyroid gland (or "goitre" in the neck) and thyroid eye disease, where the eyes become inflamed bulge (this is also known as exophthalmos, from where the phrase "exophthalmic goitre" comes – a historic name for Graves') [4]. Famous sufferers include Christina Rosetti, George HW Bush (who was treated with radioiodine) and more recently Maggie Smith and Daisy Ridley. Modern cases are usually well managed, but if left untreated Graves' disease can have serious complications [3].

Graves' disease takes its name from the Irish physician Robert Graves writing in 1834, but there are references to exophthalmos as far back as the Ancient Greek writers Aristotle and Xenophon, and the combination of exophthalmos and goitre appears in Abu-l-Fadail ibn al-Husain al Jurjani's "Treasure of Medicine" of 1110 AD. Over the 18th and 19th centuries there was a catalogue of treatments, from compresses of vinegar to the milk of thyroidless goats! [5][6][7]

I was a trainee physicist when I first heard Herbert Howells described as the earliest Graves' disease patient to be treated with radioactivity. One evening I went to listen to my cousin singing in a concert; I had just finished a long day of administering radionuclide therapies and it was a relief to sit back as the choir's voices meandered through various beautiful, meditative pieces. Glancing through the programme notes, I was brought up short by the biography of one of the composers: Herbert Howells, described as "the first person to be treated for his Graves' disease using the novel treatment of radioactivity in 1915." Although a keen amateur violinist myself, I wasn't familiar with Howells or his work. It just seemed an extraordinary coincidence after the day I'd had administering that same treatment, a century later.

A brief investigation seemed to confirm the statement – Howells was described as "the first person to receive radium treatment" and "a human guinea pig". Some references qualified this somewhat, referring to him as the first patient in the country; others refer more obliquely to "experimental treatment". Even the website "Herbert Howells Facts for Kids" (do they get much internet traffic, one wonders?) states that Howells "received a new treatment: radium injections in his neck" [8]. Everywhere from Wikipedia to his two published biographies agreed: Howells was the first. [9][10][11][12][13]

I noticed that these sources all stemmed from the world of music rather than radiology. Howells is a well-known figure in classical music, but if he were truly the first patient treated in this way, would he not also be noted in scientific literature? Surely the choral societies and music departments must have some sources? What do the early journals and the histories of British radiology say?

In the Venn diagram of "People interested in Herbert Howells" and "People interested in radionuclide therapy", the overlap region is not large (I suspect it may consist solely of myself, although I hope to enlarge it with this article). I brought up radionuclide therapy with my musical friends and drew a blank look; the same look appeared on my colleagues' faces when I asked if they had heard of Herbert Howells as an early thyroid treatment.

Before getting into my subsequent investigation, a question which may already be on your lips: who was Herbert Howells, and why should we care if he was the first thyroid RNT patient?

Herbert Howells was one of the foremost British composers of the 20th century, known especially for his choral works of great emotional depth. He came from humble beginnings: the youngest of eight children, he was born in Gloucestershire in 1892. The young Herbert was taught piano, at first by one of his older sisters, and helped his father play the organ on Sundays. Oliver Howells was a doting father and encouraged his son's musical talent, but a terrible businessman, and the family was disgraced when his business went bankrupt. As the youngest, Herbert would be sent to the butcher at closing time to ask for scraps for the family to eat, and he later described how "If I was invited to a party, when supper was served, I was sent into the kitchen" to eat it. [14]

Fortunately for Herbert, his musical ability had been noticed by the local squire, who sponsored him to get a musical education in Gloucester, the nearest big town. From there in 1912 he won a scholarship to the Royal College of Music (RCM) in London where he came under the tutelage of musical greats including Sir Hubert Parry, composer of coronation favourite "I was glad" and quasi-national anthem "Jerusalem". It was a daunting experience for a poor boy from the countryside; Herbert was so homesick he would go to Paddington Station just to watch the trains leave for Gloucester, and so poor he could only afford a ticket to stand on the platform, not board the train and travel home. [14]

Nevertheless, Howells' eagerness to learn shone through. He thrived as a music student, winning numerous awards (including a history essay competition which he won repeatedly). But his health began to fail: he suffered from fatigue and eye problems – the onset of Graves' disease, though he believed he was merely overworking. [14] Finally, at the end of 1915, he received a letter from Sir Hubert Parry, Director of the RCM, who had become something of a mentor [15]:

> *"Highnam Court, Gloucester Dec. 31, 1915*
> *My dear Howells, I am very anxious about your eyes. How do you think it would serve if you saw Dr Bower of Gloucester? He is an eye specialist of considerable reputation, and I think his advice would be worth having. Among other things he is a very keen amateur musician and would be for that reason extra glad to help. I would gladly write to him if you liked, and would also gladly provide for any expense entailed."*

This is one of many letters written by and to Howells held in the archive of the RCM (with which he was linked for decades of his life). They represent the best primary source available to investigate his diagnosis and treatment.

Dr Bower was an eminent Gloucester ophthalmic surgeon, Ernest Dykes Bower. Howells must have seen him quickly, because a flurry of letters between Parry and Howells describes Bower's early reports in 1916. In one amusing insight into their relationship, Howells writes: "He was extremely interesting and well-versed, and quite free of the narrowness which is so often attached to a specialist of any sort." [15]

Howells appears to have had the classic Graves' disease symptoms: palpitations, goitre and eye problems; he refers to it as exophthalmic goitre "in a pretty severe degree". He was given six months to live. The shock must have been unimaginable to a young man of 23 just starting to make his mark in the world of music. To add to the emotional turmoil, many of Howells' friends were enlisting to fight in the First World War. Howells himself was exempted on medical grounds. [14]

It might seem extreme to receive a terminal prognosis with Graves' disease, which can normally now be managed well. However, Britain's wartime ambassador to the USA, Cecil Spring-Rice, died suddenly from Graves' disease only two years after Howells' diagnosis, in 1918.

After seeing Bower, what happened next? Howells' two biographies focus mainly on his later life and music, but each contain a snippet. Christopher Palmer writes in 1992:

"At that time there was no known cure, and a leading heart specialist asked him if he would be willing to act as a guinea pig for radium treatment, then untried. For two years he went twice a week to St Thomas's Hospital for radium injections in the neck. This and devoted nursing by his mother – he travelled home every week to spend days in bed – cured him eventually." [16]

Paul Spicer's 1998 biography agrees: "Believing that he would have only a short time to live, the specialist dealing with his case asked Howells if he would be prepared to try out a new treatment as yet untried. Thus it was that Howells travelled to St Thomas' Hospital twice a week for two years for radium treatment. He was the first human being to be given it. That he lived to ninety must have been beyond everyone's wildest expectations. In fact, the doctors were working so much in the dark that they had no idea how much radium to give him. Eventually, they stopped when his neck (where the injections were given) showed signs of burning." [14] There is also some mention of Howells being prescribed arsenic in addition. [17]

Although Howells was a prolific letter writer, the bulk of the letters held by the RCM archive are from later in his career when he had become well-known. There are relatively few from this period. The referral to London, mention of St Thomas' Hospital or details of the treatment itself are all missing. It's clear, however, that Howells had struck lucky. The population of Britain in 1916 was around 40 million [18]; prevalence may have differed from today, but there could have been nearly half a million Graves' sufferers. Furthermore, the National Health Service would not be created for decades and Howells had no money. But, as when the local squire had paid for him to study music, fortune was kind: Sir Hubert Parry, the great composer who had taken Howells under his wing, stepped in and paid [14].

So much for the musical sources; what does the scientific literature from the time say?

First, a pause to consider the radiology scene at the time of Howells' diagnosis.

Radiology famously began with Wilhelm Roentgen's discovery of the x-ray in 1895, followed soon after by that of radioactivity (Henri Becquerel, 1896) and then of radium and polonium (Marie and Pierre Curie, 1898) [19]. The effects of radiation on tissue were soon noticed, and immediately there were attempts to use both x-rays and radioactivity in medical treatments. Pioneers such as the Curies, Henri-Alexandre Danlos and Louis Wickham, mostly based in France, experimented with applications of radium-226. It could be applied to skin conditions, embedded in silver and used on rectal and prostate cancer, and the radon gas it emitted could be collected and administered for lung conditions [20]. Outside the medical world, a radium craze exploded, with radium listed (often deceptively, thankfully) as an additive in products from cosmetics to drinking water [21].

In being referred to St Thomas' in particular, Howells had landed on his feet. Ted Burrows, in "Pioneers and Early Years: A History of British Radiology", writes: "The X-ray Department of St Thomas' Hospital in 1912 was one of the most complete and advanced in Britain." Interestingly, he continues "Unlike the situation at some other teaching hospitals at that time, therapy and skin patients did not preponderate at St Thomas's Hospital." [22] It would be interesting to know why Howells was referred to St Thomas' for his therapy – perhaps Bower had a contact there? Or Parry did?

Given the date of Parry's initial letter, Howells' cannot have started treatment before 1916. The department had recently been taken over by Archibald Reid, a significant figure in early radiology. Reid and Howells shared similarities: both were young, energetic highfliers of whom much was expected; both were interested in innovation; both were working in fields that were developing apace, looking to Europe and beyond. Reid had been President of the Electro-Therapeutical Section of the Royal Society of Medicine and moved to St Thomas' in 1912 from King's College Hospital, where he had introduced x-rays [22]. The fact that Reid later developed radiation dermatitis to his fingers suggests he was very much a hands-on presence – Reid may have treated Howells himself.

Wonderfully, we have a description of the St Thomas' Hospital X-Ray Department written by Reid himself, published in 1914. Reid describes the installation in 1913 of "two X-ray treatment cubicles, on similar lines to those at present used in the London Hospital". From his description of the other rooms in his department (a large radiography room split in two for imaging patients, a dark room, workshop and office), these cubicles must have been where Howells was treated. The department was staffed by Reid, "three qualified clinical assistants, two other assistants, and one developer." [23] Of course, the onset of war may have altered the exact staffing by the time Howells was treated in 1916.

The same report includes a "Summary of Work in the X-Ray Department at St Thomas's Hospital for the Year 1913". This includes 6501 radiographic examinations, including the unpleasant-sounding case of "a safety-pin embedded at the bifurcation of the trachea". It goes on to list the therapy cases, including "Exophthalmic Goitre – Five cases improved, still under treatment; two improved, but ceased attending; two not improved...The usual filtered doses were given once or twice weekly with occasional intervals." [24] Here then is evidence that three years before Howells started treatment there were patients at the same department with the same condition and a similar treatment regime.

Fascinatingly, the corresponding report for 1916, the year Howells was treated, contains several references to radium: for carcinoma of the mouth (eight cases), the tongue (seven cases) and, crucially for our investigation: "Malignant glands of neck, 13...treated by radium, 5" [25]. Presumably Howells was one of these five.

St Thomas' was not alone in publishing records of radium treatment for exophthalmic goitre. The British Medical Journal carries a "Report on the Radium Treatment at the Royal Infirmary, Edinburgh, during the Year 1914" by Dawson Turner. This lists 63 patients, of whom six were for exophthalmic goitre or Graves' disease. Turner used radium screened through silver, causing a "great improvement" in their symptoms [26].

Turner was another titan of early radiotherapy. An enthusiastic early adopter, he built an x-ray set in his own house within a year of their discovery. By the time of Howells' treatment, Turner had already published multiple papers on the use of radium in medicine, including "Radium rays in the treatment of hypersecretion of the thyroid gland" (1913). In this, he describes how x-ray treatments for Graves' disease had become "orthodox", but that radium had a similar clinical effect with advantages including "a perfectly definite dose...repeated as often as desired", applied "without noise or excitement while the patient is in bed" [27]. Turner lists four cases for whom he replaced x-ray therapy with radium. Typical doses are about 400 mg.h per session (through 1mm silver). Since the Curie unit (Ci) was originally defined as 1g of radium-226, and a typical quantity of radium was c. 50mg, this dose is equivalent to 0.05Ci/1850MBq in place for a duration of 8h.

This would have given a hefty dose rate – nearly 3Sv/hr through 1mm of lead, at 1cm distance [28]. No wonder many of the early operators suffered the consequences; Turner himself lost two fingers and an eye. He went on to die of cancer; his name is listed on the "Monument to the X-ray and Radium Martyrs of All Nations" in Hamburg.

In his 1913 paper, three years before Howells' treatment for exophthalmic goitre or Graves', Turner writes that he was "unaware of any previous use of radium for this condition". He was mistaken, however: even more crushing for the hypothesis that Howells was "the first human being to be given radium" is a 1905 paper entitled "Exophthalmic Goitre Reduced by Radium", by Robert Abbé. In this Abbé, a New York surgeon, describes the difficulty of operating on Graves' disease goitres: "we would all welcome a remedy, which as yet has not been found... The case about to be reported is the only one, so far as I know, which has been presented for study to which radium has been applied." [29]

Abbé describes the case of a twenty-one-year-old woman with exophthalmic goitre. It occurred to Abbé that "the application of radium outside a goitre would be ineffective; but within the growth we might see more striking results." He therefore embedded a sterilised tube of radium within an incision in the neck, kept it in pace for 24 hours, then removed it and dressed the wound. The treatment was apparently a great success: the patient now "plays tennis every day". [29]

Abbé, a founder of radiation oncology, was a friend of the Curies. Less than five years after they discovered radium, Abbé brought back to New York a supply from Marie Curie's Institut du Radium in Paris. A review of his work covers a huge number of clinical conditions to which he applied radium, including cervical cancer, skin conditions, breast cancer, sarcomas, uterine fibroids and tonsils. There appear to be almost no body parts to which he couldn't envisage applying radium. He later died of anaemia, probably radiation-induced; he once said "no one who ventures to use radium in practice should do so without first testing his particular specimen on his own skin." [30]

So, we have a case study of radium treating Graves' disease in 1905, a decade before Howells' diagnosis. It's not looking good for the story that Howells was the first.

Returning to Britain, however: in Turner's 1913 paper, another name jumps out: Neville Finzi, radium pioneer and later president of the Rontgen Society. Finzi is also a name immediately recognisable to musicians as that of the composer Gerald Finzi; in fact, Neville and Gerald were cousins. Howells and Gerald Finzi were friends, and on Gerald's death in 1956, Howells composed a beautiful musical tribute to him, "Finzi's rest".

In 1916, when Howells was diagnosed, Neville Finzi was working at St Bartholomew's Hospital. He had already presented extensively on radium in medicine: a presentation at the Royal Society of Medicine in 1907, a 1909 paper "Radium in the treatment of malignant growths" and "Rontgen Therapeutics" in 1913 [31][32]. He once said: "I believe that every operation for cancer should have prophylactic radium treatment as a routine measure." Clearly this was a good man to know if you needed a novel radiation treatment.

It would be hugely satisfying if Howells' referral to London for radium treatment had come via Gerald Finzi and his pioneering cousin, tying the musical and radiology worlds even closer. However, it is not to be – at the time of Howells' treatment, Gerald Finzi was only 14, and he and Howells would not become close until years later. It remains, however, an extraordinary coincidence that one of the musical names with which Howells is often bracketed also belongs to one of the pioneers of the treatment that was to save his life.

Reid and Neville Finzi were both active in institutions including the Royal Society of Medicine. It's likely that they knew each other and Reid may even have been present at Finzi's 1907 talk. It's not unreasonable to assume that Reid's techniques in treating his patients at St Thomas', including Howells, may have mirrored aspects of Finzi's procedures from his 1909 paper. In this, Finzi gives a remarkably thorough description of radium's physical characteristics and practical uses, given that it had only been discovered a decade previously. He describes the use of metal filters (lead or silver) to remove lower energy radiation and the alpha and beta components, leaving higher energy "ultra-penetrating" gamma rays. His treatment equipment consisted of "a glass tube containing 50 mg of pure French radium bromide [presumably obtained from the Curies' lab in Paris], of a silver tube 0.5mm think, a lead tube 1 mm thick, and lastly, of a thick lead case to carry it in... for introduction into cavities, the metal tube is tied up inside a rubber tube." [31]

Finzi's paper debates the biological effects on cells, without the benefit of an understanding of DNA or radiobiology. He worried that giving a dose below curative level might stimulate malignant cells. He describes the onset of erythema (skin reddening), an effect Howells apparently experienced. [31]

Herbert Howells took several years to recover, but he does not seem to have suffered any long-term ill effects – radiation dermatitis or anaemia, for example. There is also no record of further symptoms of Graves' disease later in life – a complete cure seems to have been achieved. He was able to resume his career, but his mentor Sir Hubert Parry, who had financed and possibly arranged his treatment, never saw it: he died of Spanish flu in October 1918, weeks before the war's end.

Howells had been lucky, not only in receiving such a novel therapy, but in avoiding conscription on medical grounds. Many of his friends were not so lucky; one, Francis Warren, was killed on the Somme in 1917 aged only 21; Howells composed a piece ("Elegy") in his memory [14].

In 1920 Howells married his long-time sweetheart Dorothy, after an engagement delayed by his health and precarious finances. Two children followed: Ursula in 1922 and Michael in 1926. Contentment seemed assured, but in 1935 tragedy struck: nine-year-old Michael caught polio on a family holiday to Gloucestershire, and died within days. His parents were beyond devastated. Ursula wrote of how, despite Howells' lack of religious belief, from this period he would practically "live in church". Herbert and Dorothy travelled constantly from London to visit Michael's grave, on the train which years before, as an impoverished and homesick student, he had watched longingly but which he now described as "a sort of spiritual murder-on-wheels" [14].

It was Ursula who suggested channelling his grief into music. So, out of horrendous circumstances, Howells' musical masterpiece was born: "Hymnus Paradisi", or "Hymn to Paradise", a 45-minute-long choral work described as "heartbreakingly beautiful" and "a little piece of heaven". Howells kept the piece, which bears the heart-rending subtitle "Take him, earth, for cherishing", privately for decades until he was persuaded have it performed in 1950 [14][33].

The Grove Dictionary of Musicians sums it up: “The death from polio of his own nine-year-old son in 1935 affected him at the deepest level, and it is arguable that most of his subsequent works were, to a greater or lesser degree, influenced by it.” [34]

In 1956 there was another brush with serious illness when Herbert’s daughter Ursula, now 34 and a successful film actress, was hospitalised with tuberculosis. As with her father’s novel radium therapy, medical advancements were just in time [35]. The contrast is tragic with Michael’s fatal polio, twenty years before the first vaccine was developed and at a time when “there was only one iron lung in London, and it was on the other side of London” [14].

Howells’ later life was characterised by teaching, composing and generally becoming an elder statement of classical music. He was commissioned to compose for many events of the 20th century: the birth of Prince Charles, the Coronation, the death of Kennedy. Never far from his mind, though, was the tragedy of losing Michael. A friend described him as “relatively cool, urbane, debonair, very English personality; and deep down there was an absolutely boiling cauldron” [14].

Howells’ character contained many contradictions. He found his vocation in an outpouring of music to be sung in church, despite having no faith himself. Like the treatment that had saved his life, he was modern and innovative, but he also drew inspiration from English folk music and the Gloucestershire countryside of his youth. He was a devoted family man, but had a string of long-term affairs.

Howells taught well into his 80s and was made a Companion of Honour in 1970. He died in 1983 at the age of 90; his ashes are buried in Westminster Abbey alongside a host of famous musicians, including some he knew personally.

Archibald Douglas Reid, head of department at St Thomas’ when Howells was treated there in 1916/17, also went on to great things. He was President of the War Office X-Ray Committee, for which he was knighted [22]. He devoted great energy to his institutions; just as Howells gave much of his career to the fledgling Royal College of Music, Reid was a founding member of the British Association of Radiology and Physiology and the Society of Radiographers, serving as its first President.

In 1921, Reid was a member of the “X-ray and Radium Protection Committee” which published some of the first radiation protection guidelines [22]. These included using forceps and lead-lined boxes, and not remaining “in the vicinity of radium for longer than is necessary”. The precautions came too late for Reid himself, who had already developed radiation dermatitis. In 1922, the tomb of Tutankhamun was discovered in Egypt by the archaeologist Howard Carter. Carter invited Reid to carry out an x-ray of Tutankhamun’s mummy, but Reid was too unwell. He died in Switzerland in 1924 aged 52 [36]. By this time, he was Sir Archibald Reid, KBE CMG MRCS LRCP DMRE [22].

Graves’ disease treatment has changed beyond recognition. If Howells were diagnosed today, he might be offered thyroid surgery (typical for patients with severe eye problems), medications to reduce hormone production, or radioactive iodine treatment. Radioiodine treatment, which is an oral administration rather than insertion of a sealed needle, was first performed in 1941, and is now well established, with tens of thousands of treatments now performed worldwide annually. It sits among a range of modern radionuclide therapies, including radium-223, lutetium-177 and yttrium-90, each used for a specific clinical condition [6][37][38]. Radium-226 therapy, meanwhile, declined as evidence of its hazards mounted. Legislation controlling unnecessary radiation began to grow from the 1960s, and by 1976 it had been effectively phased out.

Returning finally to the question that started this whole investigation through the science, medicine and music of the 20th century: was Herbert Howells – titan of English music, Companion of Honour, composer to Queens and Presidents – the first human treated with radioactivity for Graves' disease, as so many of his biographies say? Sadly, the evidence suggests otherwise.

This leaves a new question: if Howells wasn't the first, where did that rumour come from? I have not been able to trace the origin of the story. Could it have come from Howells himself, who liked to name drop and chat with friends and students over drinks into the early hours?

Howells was, however, treated within a decade of radium's discovery, with a therapy novel enough for hospitals to publish their annual work as a list of case studies. His treatment enabled him to live nearly 70 years more and hugely influence classical music, despite being told he had six months to live. It is poignant that the pioneers of this treatment were themselves to die young.

Howells' life contains elements that speak to everyone: huge personal tragedy; moments of incredible luck; success mingled with times it seemed he would not live up to expectations. He touched thousands of lives through his teaching and wrote music of heartbreaking intensity. His biographer Paul Spicer writes "he can put a voice to our spirituality, our very sense of being, and in a way almost too human, to that deepest of all senses, longing." [14] Howells' music is his legacy, just as radiation treatments performed in hospitals worldwide today are the legacies of Archibald Reid, Robert Abbé and Dawson Turner.

To those unfamiliar with Howells' music who would like to dip their toes in, a good place to start might be "King David" or "A Spotless Rose". The latter is a Christmas carol of haunting melancholy, about as far as possible from Jingle Bells. For greater investment of time and emotional energy, "Hymnus Paradisi" has a "sense of loss...inseparable from a visionary splendour" [34].

No one can tell how much of this would have been lost had it not been for that pioneering treatment back in the last years of the First World War. And perhaps that matters more than being the very first.

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A History of Bone Mineral Measurement

Edwin Aird

Introduction

There was an early awareness that low bone density could cause fractures in humans; but there were not methods to measure bones with sufficient accuracy to be useful as a diagnostic tool. Simple radiographs allowed for visual assessment by the 1920s, but demineralisation was qualitative and subjective. It appears that at least 30%-50% bone mineral loss has to occur before it becomes apparent on film, particularly in the spine.

Sir Astley Paston Cooper (1822) noted the association between bone abnormalities and fractures. ("He noted the increased fragility and 'lightness' of bones which he connected to a higher risk of fractures"). In 1941 the American endocrinologist Fuller Albright noted the association between the loss of bone in the vertebral bodies and fracture risk. [1]

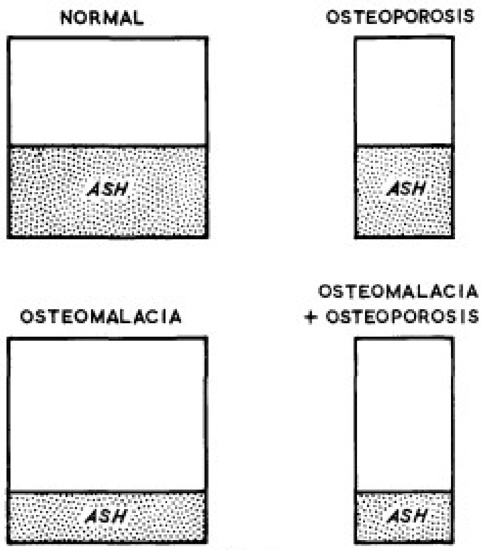


Fig. 1.

Diagrammatic representation of skeletal mass and skeletal mineral in the normal state and in metabolic bone disease.

[1] Editorial note: Fuller Albright (1900-1969): Fuller Albright. His concept of postmenopausal osteoporosis and what came of it: A P Forbes: Clin Orthop Relat Res. 1991 Aug:(269):128-41. Abstract: Fifty years ago Albright contributed the following to understanding osteoporosis: (1) He recognized it as a deficiency of formation, not of mineralization of bone matrix; (2) he observed that 40 of 42 patients with osteoporosis before age 65 were women past menopause or young women post oophorectomy; (3) he concluded that oestrogen stimulates osteoblasts (a conclusion later challenged); (4) he demonstrated by metabolic balance studies that oestrogen causes a positive calcium balance in postmenopausal osteoporosis; (5) he introduced periodic progesterone to prevent or treat endometrial hyperplasia from prolonged oestrogen therapy; and (6) he showed that long-term therapy arrested vertebral damage and height loss in postmenopausal osteoporosis and prevented them if started early. Since Albright's time, more sensitive methods of assessing bone density have replaced conventional roentgenograms. Some large-scale trials of oestrogen have indicated increased bone density and fewer fractures. Unopposed oestrogen increases risk of endometrial cancer and decreases mortality from other cancers, myocardial infarction, stroke, and osteoporosis. Trials of calcitonin, diphosphonates, fluoride, vitamin D, and high calcium intake have not proved more effective than oestrogen. https://pubmed.ncbi.nlm.nih.gov/1864030/

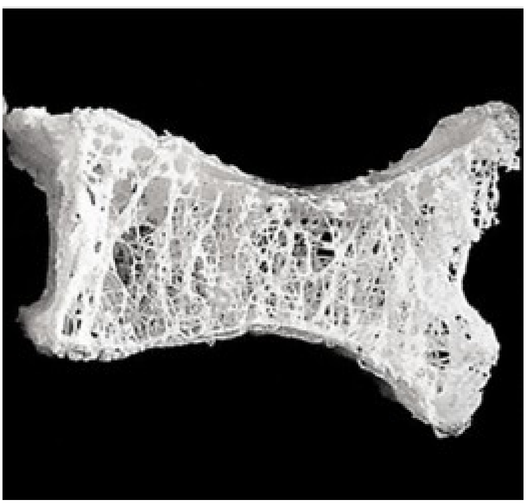
The two main forms of bone disease relevant to this paper have been nicely defined by Barnett & Nordin (see below BJR 1961 Annual Conference Proceedings)

Osteoporosis: (the word "osteoporosis": "porous bones", was introduced by a French pathologist Jean Lobstein in 1833): a disorder causing reduction in bone mass, without any known change in chemical composition (see Aird, Grimley Evans Sher - below).

Osteomalacia: The adult form of rickets: a progressive fall in mineral content due to a failure of deposition of mineral. (see Kerr, Aird, etc. - below in section)

Early Methods.
All bones consist of cortical and trabecular regions. Cortical bone is the hard outer layer of bone (particularly evident in the long bones) with a typical density of 1,2g/cm^3; trabecular bone is the porous inner network of bone filament that provide structural flexibility and a typical density of 0.3-0.5 g/cm^3.

The Singh Index
Doctors involved with bone (mainly radiologists) have worked with both trabecular and cortical bone. An interesting early paper is by M Singh: "Femoral trabecular pattern index for evaluation of spinal osteoporosis" (Annals of Internal Medicine 1972; 77:63). He states that this (The Singh Index-6 Grades) is based on a pattern in the of the upper end of the femur trabecular bone, and can be used to evaluate bone loss. However, later work shows that the Singh Index does not correlate with bone mineral density measured with DXA (see below: now accepted as the gold standard for measuring bone mineral.



A compressed osteoporotic vertebral body with reduced trabeculae and density.

Some detailed radiographic methods.

1) Distances (Radiogrammetry) on radiographs: The Metacarpal Index (MCI) measured from radiographs; but not that useful since cortical bone experiences slow changes compared with trabecular bone.

2) Radiographic absorptiometry using a reference standard included on the radiograph.

Use a radiographic technique recommended by Keane, Spiegler and Davis (1959; 32:162)) bone mineral content has been measured in vivo in the index metacarpal.

The hand is pronated on a plastic surface inclined at 45deg to the horizontal inside a bath of water. A wedge containing $ZnCl_2$ solution (to calibrate the film) is placed alongside the hand (similar to Katranoushov see figure below). Radiographs are taken at 50kV with FFF 150cm and FOF 25cm.

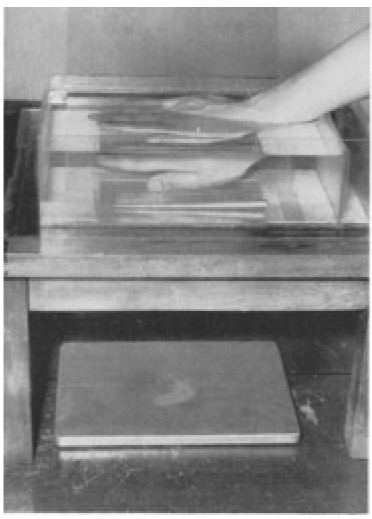
Bone mineral is measured in the compact bone at the mid-shaft and in the spongiosa of the epiphysis at a distance of 8% of the bone length form the metacarpal. Hydroxyapatite concentration is determined in g/cm. For healthy adults: 1.1-1.3 g/cm3.

2b) I Katranoushov and O Dyankov (Vol 45 (531): 212) (see figures)
Also using a water bath with a ZnCl2 bath (figure above)

For the spongiosa in the epiphysis of the index metacarpal (140-300mg/cm3)

Left Photo: the hand is shown pronated on a plastic triangle inclined at 45 deg. to the base of a water-bath. The reference wedge containing a solution of $ZnCL_2$ is placed parallel to the hand.

Right Photo: the hand is partly supinated on the plastic triangle. This provides a projection of the index-metacarpal perpendicular to that shown on left.

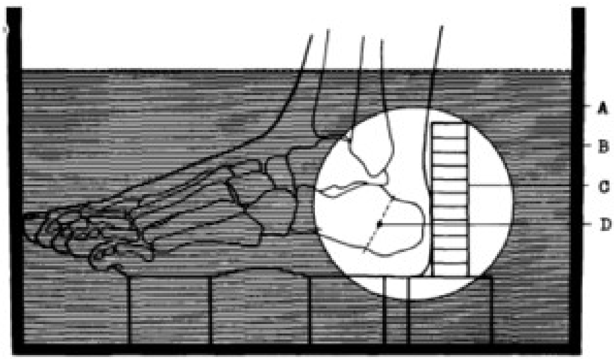


3) The title of the BIR annual congress in 1961: "Radiological Assessment of bone density". Three papers are written up in BJR 1961; 34(407).

a) Definitions as given by Ellis Barnett and BEC Nordin (Glasgow) (see above)

b) KM Mayo (Royal Marsden) looked at a quantitative method of measuring normal adult bone of the calcaneus in a water filled Perspex tank together with an aluminium wedge:

14 steps of 0.5-7mm) to standardise the measurements from radiographs (see figure below).



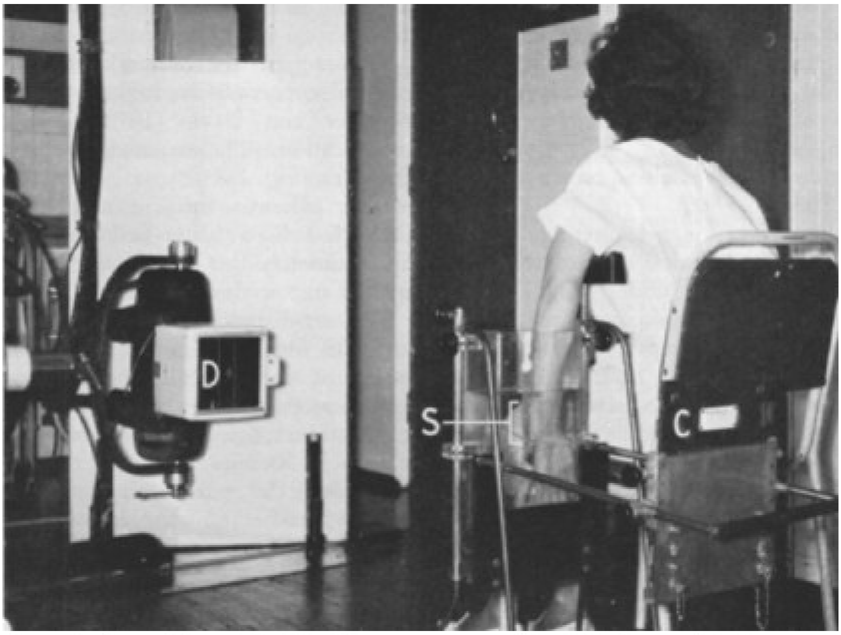
Lateral view of arrangement used for taking the absorption film of the calcaneum. A Water-filled Perspex tank. B Exposed field. C Standard wedge. D Point of measurement.

c) Frank Doyle (Hammersmith): "Ulnar mineral concentration in metabolic bone disease". He followed Keane techniques (1959; see above). (Under his *acknowledgments: "I am indebted to Prof R E Steiner. Within hours of my arrival in his department he indicated the need for quantitative measurements of bone density and placed the problem in my lap").*

Method m (photo below):
i) Forearm placed in a water both together with aluminium wedge (0.5-7mm). 3 films + 4th to measure width of ulnar. He gives details of his technique, including:

i) Film: standard tungstate screen; careful handling in dark room (no light).
ii) Microdensitometer to determine density at 8 points along the ulnar.

Doyle spells out the details of this technique (with their associated ulna BMC vs distance along ulna (and in many cases associated radiographs of spine, pelvis or forearm bones), used on 9 patients with very different diseases, including a 40 y old woman with severe post pregnancy osteoporosis (9 years ago) put on a high calcium diet...and demonstrating high ulnar bone mineral, but very poor spine mineral content.



The production of the radiograph. D=X-ray source with light-beam diaphragm. S= aluminium step-wedge mounted on Perspex strip and suspended in water-bath adjacent to the ulna. C=cassette. Note the "exit-distance" between the water-bath and the cassette.

Later, Frank Doyle (as recently as Doyle et al, BJR, 1967; 40:241) writes on the limitation of the plain film of the spine in the assessment of osteoporosis. It had become obvious that nearly 30% of bone mineral loss was necessary before it becomes apparent on radiographs.

Which leads to the next phase of development for bine mineral measurement.

The next phase: the development of photon absorptiometry (using narrow beams of photons, either gamma rays from a radionuclide, or selected energies of x-rays).

The following workers used the simple principles of attenuation of a narrow photon beam by matter, in this situation: soft tissue and bone. With a single photon beam it is possible to measure the amount of bone mineral in the beam provided that the thickness of soft tissue is known (see West and Reed below). When it isn't possible to define the thickness of soft tissue, it is necessary to use two photon energies to find a solution to the absorption equations. Hence the later term: Dual Energy (X-ray) Absorptiometry (DEXA). Earlier machines used photon beams from radionuclides (particularly Gd 241); but later machines used 2 energies of x-rays which gave greater efficiency (shorter scan time etc)

Cameron (Wisconsin)

Key Contributions of John R Cameron (in bone mineral measurement)

Developed in vivo measurement techniques with his colleagues.

Initially using single photon absorptiometry.

Pioneered dual-photon absorptiometry (DPA), which allowed spine and femoral neck bone mineral to be measured accurately.

Many research papers, particularly with Dick Mazess (who went on the establish the Lunar Systems and Sorenson).

(Note date of this reference only 2 years after the BIR annual conference discussed above 1961.) "Measurement of Bone Mineral in vivo: an improved method" ,JR Cameron and J Sorenson (Science 1963; 142:230)

Abstract:

> The mineral content of bone can be determined by measuring the absorption by bone of a monochromatic, low-energy photon beam which originates in a radioactive source (iodine-125 at 27.3 keV or americium-241 at 59.6 keV). The intensity of the beam transmitted by the bone is measured by counting with a scintillation detector. Since the photon source and detector are well collimated, errors resulting from scattered radiation are reduced. From measurements of the intensity of the transmitted beam, made at intervals across the bone, the total mineral content of the bone can be determined. The results are accurate and reproducible to within about 3 percent.

My connection: Aird and Pierides 4th international conf on BMM (in Toronto) 1978 Bethesda 1980 NIH Publication No 80-1938: 217-30.

RR West and GW Reed BJR 1970;43(516): 886-893.

Femur with Am241 beads forming a line source 2x10mm (100mCi) on the left-hand arm of a skull x-ray stand.

The detector is a sodium iodide crystal 1.5"x 0.5" thick coupled to a photomultiplier tube with a lead lined collimator 4cm long and 5x15mm in cross section. (photo)

Scans are affected by moving the patient on a motorised chair.

Theory: constant soft tissue so only single photon source required to calculate bone mineral.

Scanned across the distal end of femur shaft at approximately a 1/5 of distance form lateral epicondyle to greater trochanter (cortical bone).

J E Compston et al "Bone mineral content in normal UK subjects" BJR 1988; 61: 631-636

T Overton et al, "Bone demineralization in renal failure: a longitudinal study of the distal femur using photon absorptiometry", BJR 1976; 49:921-925

[This was one of the inspirational studies that helped the direction of my work at Newcastle]

The bone mineral content of the lower end of the femur was measured by photon absorptiometry in 87 patients with chronic renal failure. The gamma-ray photon source was Am241.

The development of photon absorptiometry in Newcastle University and General Hospital was prompted by an unusual source: Ian McCullum from Department of Industrial Health. For many years Dr McCallum had been interested in the impact of various metal dusts on the health of workers, particularly in the unique (for the UK) factory on Tyneside where Antimony was smelted. Antimony is an extremely useful metal (it was first used by the Romans in their emetic cups!!): batteries etc.

Antimony trioxide dust can give rise to shadows resembling pneumoconiosis on lung radiographs. But to investigate means of quantifying the amount of antimony in workers lungs it was necessary to develop a very accurate method of photon absorptiometry.

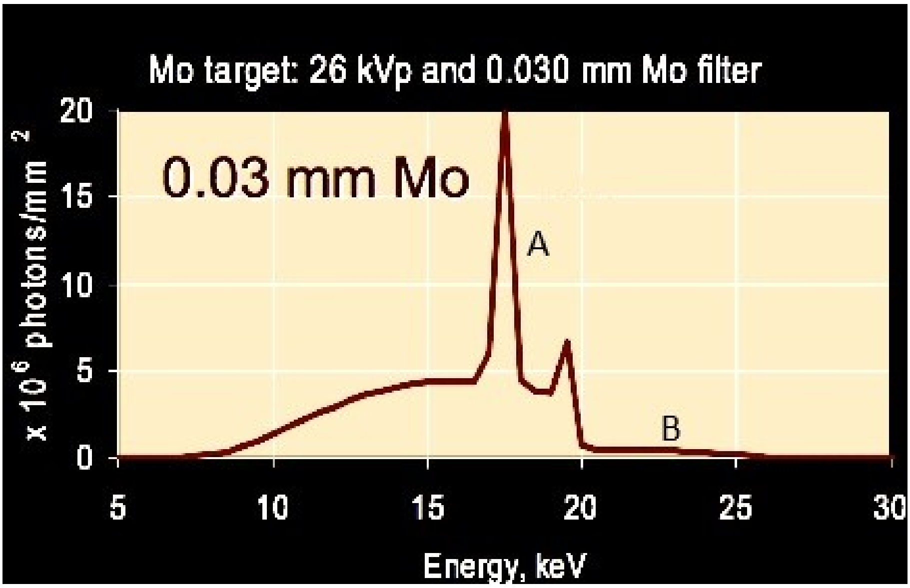
The method of using K absorption edge absorptiometry to measure antimony dust was developed by Day, Aird and McCallum.

This technique involves measuring the abrupt change in x-ray absorption of a sample containing antimony when the x-ray energy exceeds the K edge energy (which is 30.5keV for antimony. By using narrow x-ray beams with very specific energies just above and just below this energy the concentration of antimony in the specimen (in this case the worker's lungs) can be calculated.

The x-ray beam had to be positioned over the lung (by observing the increase in count rate) so that it was not traveling through any bone (ribs). Typically, it was possible to find six such positions through each lung.

(This particular image is that of a coal miner showing a high amount of dust in the lungs. Only a few antimony workers suffered this amount of dust, and level of pneumoconiosis)

MJ Day (1977) suggested the principle of absorption edge x-ray absorptiometry: this uses two photon beams of energies above and below the absorption edge of antimony (30.5keV). By measuring the difference in absorption of these two beams it was possible to determine the amount of antimony in the beam to within 1mg/cm^2 (Results showed a range of antimony in workers' lungs of 0-11mg/cm^2; there was a significant association between employment duration and lung content) This was a remarkably accurate measurement of antimony dust in-vivo.



A Peaks are the characteristic x-rays of molybdenum.
B Strong absorption of continuous x-ray spectrum by molybdenum filter

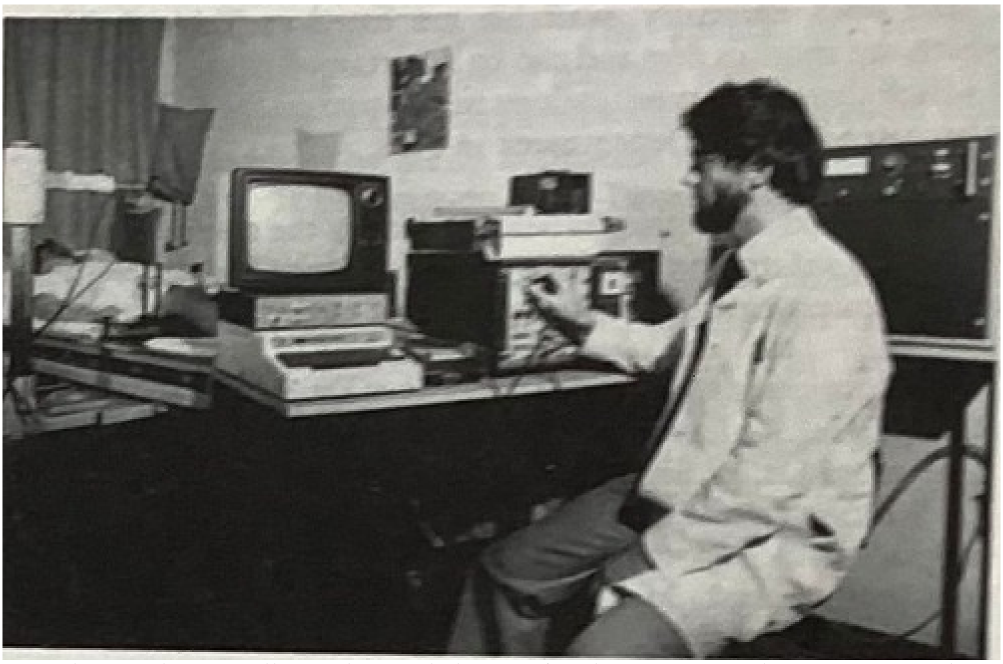
It may be of interest to the reader that the principle of the use of the absorption edge is used in mammography. The optimum energy for mammography is between 15 and 25keV. By use of a molybdenum target and (K-edge) filter of molybdenum (Mo/Mo target /filter) a highly selective beam of x-rays is produced which is ideal (both from an imaging and a radiation dose perspective) for breast imaging of the smaller breast. For thicker breasts a Rh/Rh target filter (rhodium) combination is preferable. This type of K-edge filtration allows only the useful x-rays through, which will show micro-calcifications clearly and keep the radiation dose low.

It was my job to develop the equipment to a greater degree of automation and I participated in a large set of measurements of the human subjects. It is important to note that this method of in-vivo measurement of elements in the body can only be used for sufficiently penetrating x-ray energies – so only for metals where the absorption edge is sufficiently high.

Development of absorptiometry for bone mineral

The equipment use for the antimony measurements had many of the features that could be developed into a x-ray absorptiometry system to measure bone mineral , following principles used by Cameron; West and Reed (see above): viz: An X-ray table; and x-ray set; A Nuclear Medicine detector system: scintillation counter and PM tube with counting equipment. For bone mineral, count rate was used instead of total count.

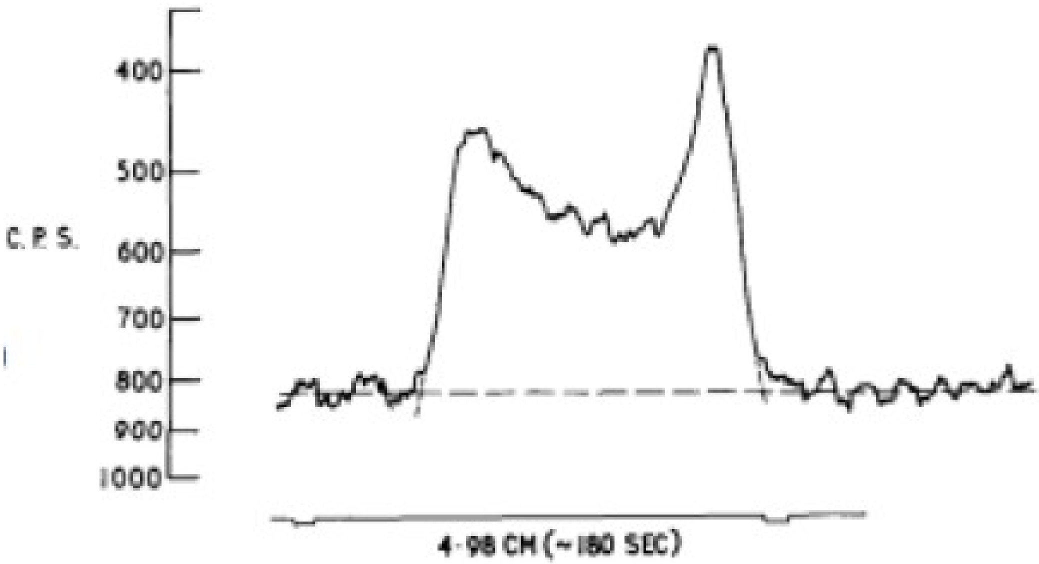
It was decided to start to develop the absorptiometry equipment as follows. (The equipment is shown in the figure below from Newcastle Regional Medical Physics, 1978)



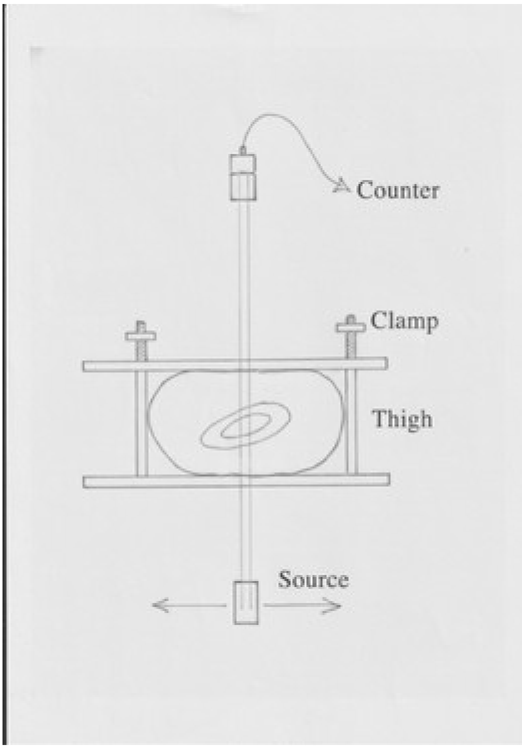
The x-ray beam: this initially used a single beam of K characteristic photons scattered from a target of samarium, with an energy of 42keV. The arrangement was: a primary x-ray source – a superficial radiotherapy x-ray tube – to give a constant potential x-ray energy continuously for long periods of time. Its beam was directed onto the secondary target (samarium). The scattered beam, at right angles to the primary, was then directed vertically through a collimator: through the patient, then enters a collimator before impacting on the scintillation detector immediately above the patient.

Measurements of attenuation coefficients in various pure elements indicate that the beam is virtually monochromatic with a quantum energy of 42 keV. The detector used was a scintillation counter. The pulses from this were analysed and fed into a multiscale where the completed scan was stored until punched on to paper tape for computer (PDP8) processing (later the data was fed directly into a microprocessor which allowed the bone mineral result to be calculated directly). At each visit a measurement of bone mineral in mass per unit length was obtained and this was called the Bone Index. Serial measurements from each patient were fitted by a straight line using the method of least squares in order to calculate the rate of change and allow comparison between patients. The resulting rate of change was tested for its difference from zero slope.

The first site to be measured was the femoral shaft (similar to West and Reed). The patient 's thigh was held in a Perspex box to give constant soft tissue thickness over the region to be scanned. (Just visible on the photograph above). The x-ray source and detector were linked and driven across the leg at a constant speed. The count rate was recorded on a computer (several computer systems were developed over the period of use (1978-1987?). The area under the curve (see figure below) gave a measurement of bone mineral, which was calibrated using a standard bone mineral sample.



Logarithmic count rate of femur scan



The Newcastle BMM system.

The source was an SXT X-ray set (see Invisible Light....) operating at 100kVp. The primary beam is directed onto a target of samarium to produce characteristic x-rays at 40keV, very suitable for the total thickness of the thigh. The detector (a sodium iodide scintillation counter) directed the counts into a microprocessor (developed by the Regional Medical Physics computer unit in 1978).
This single energy beam attenuation system allows the bone mineral in the beam to be calculated. The total bone mineral in the femur is determined by scanning this beam across the thigh at a definite distance from the patella.

The use of the Newcastle BMM system.
The main clinical demand arose from two major university department sat Newcastle: the endocrinology team (led by Prof D N Kerr) and the geriatric team (led by Professor Grimley Evans).

Renal Patients and bone mineral measurements.
D Kerr was interested in what became known as Newcastle Bone Disease. Renal dialysis patients naturally lose bone mineral during their period on dialysis, but in Newcastle this was aggravated by the use of mains water that contained aluminium. "On that very same day I went to the waterworks on the north of the Tyne and saw them putting aluminium sulphate into the water (Wellcome Witnesses:Volume 37, History of Dialysis in the UK1950-1980).

We measured very many groups of kidney patients (renal dialysis, and transplant patients over several years to determine bone mineral loss. (see references: Kerr, Ward, Aird; Pierides and Aird)

Part of the abstract below is from BJR 1977; 50:350-356. "Photon absorptiometry after successful renal transplantation", EGA Aird and AM Pierides

Photon absorptiometric measurements of the right lower femur were carried out at regular intervals of one to three years in 58 recipients of renal transplant.
During the first six months after transplant, 57% showed a significant and abnormal rate of loss of bone mineral, while at 30 months after transplantation only 17% showed a significant loss.

Regular photon absorptiometric measurements provide an accurate, informative and non-invasive technique for following changes of bone mineral content after successful renal transplantation.
See also: Aird and Pierides 4th International Conference on BMM (in Toronto) 1978 Bethesda 1980 NIH Publication No 80-1938: 217-30.

[See also: EGA Aird, TG Feest and DNS Kerr "Bone density in renal patients" a paper at: BIR Benign bone disease-role of radioisotope techniques. BJR 1979; 52:251}

Osteoporosis and bone mineral measurements.

Osteoporosis is a metabolic bone disorder characterized by low bone mass and microarchitectural deterioration (with an) increase in bone fragility and susceptibility to fracture.
DEXA is now recognised as the reference method to measure bone mineral with high precision and reproducibility. The WHO has established DEXA as the best technique for assessing Bone Mineral Density in postmenopausal women (see ref 2,3 in DXA scanning in Clinical Practice A El Magraoui C Roux (QJM: An International Journal of Medicine 2008;101(8): 605-617
The work on fracture patients (with osteoporosis) was complicated.
Most useful sources are, from Grimley-Evans group, a letter by JL Sher and J Stevens and JL Sher and EGA Aird, J Bone Joint Surg[Br], 1983; 65:660

"Trochanteric (extracapsular) fractures present a spectrum of bone injury form simple two-part fractures to complex comminuted configurations. WE have tried to correlate the degree of comminution in such fractures with a measure of bone state as well as femoral photon absorptiometry; no correlation was found. Clearly the mechanism of injury (whatever event this describes) is more important in determining the bone configuration that the severity of the osteoporosis."

Commercial development of Bone Absorptiometry Systems.

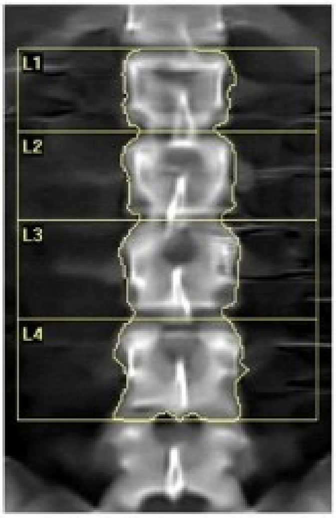
The main aim was to develop systems that could measure the main bone of interest connected to fracture risk: neck of femur; vertebral bodies (particularly lumbar vertebrae). The first systems used a radioactive source Gd241 that emitted two photon energies (44 and 100keV), and was ideal for this purpose (apart from the need to replace the source regularly because of its relatively short half-life.
Later systems used either filtered x-rays or rapidly changing primary kVs.

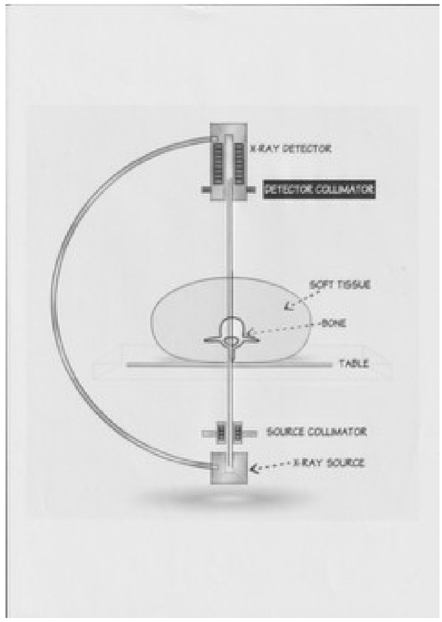
A dual energy x-ray absorptiometry system developed to measure BMM where the soft tissue cannot be constant across the bone site (particularly spine and femoral neck).

The recent systems use a primary beam of x-rays, that is filtered by two different elements to give x-ray beams with spectra that peak at two different energies, (typically 40-50keV for the low energy beam and 70-100keV for the higher energy).

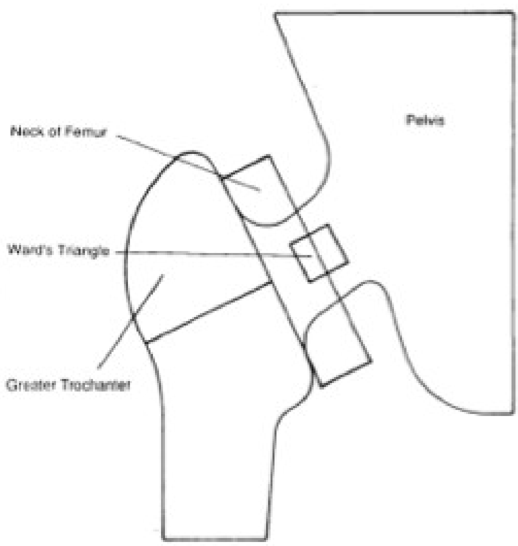
This source and detector can be scanned across the patient to give a total BMM of the spine at this level. (usually the lumbar vertebrae: L1-L5 are scanned). More advanced models allow the source detector system to be rotated around the patient and then scanned.

Lumbar spine





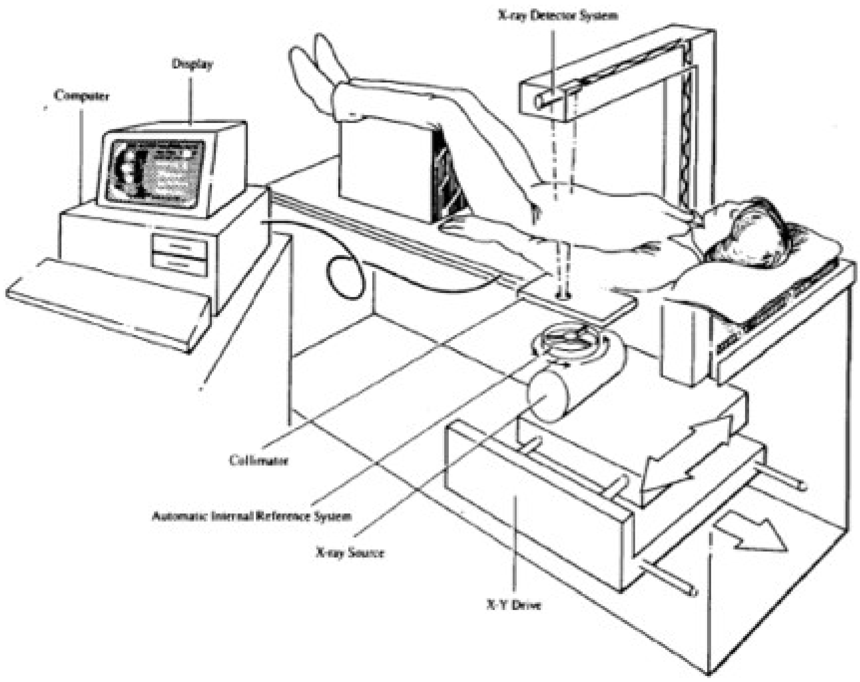
Anatomy of the Proximal Femur



Hologic QDR 2000:

The QDR 2000 uses an energy switching mechanism (potentials 70kVp and 140kVp) to give effective photon energies of 43keV and 110keV. A fan beam of x-rays is produced by a narrow-slit collimator coupled to a 32- detector array. The scanner then only needs to move along the length of the patient.

Below: Schematic diagram of the QDR 1000.
British Journal of Radiology July 1989.
This patient position flattens the lordosis of the lumbar spine.



Lunar (developed by D Mazess) used two x-ray photon beams (heavily filtered primary beams 70 and 100keV; unlike Aird's characteristic x-ray beams, and therefore of greater intensity).

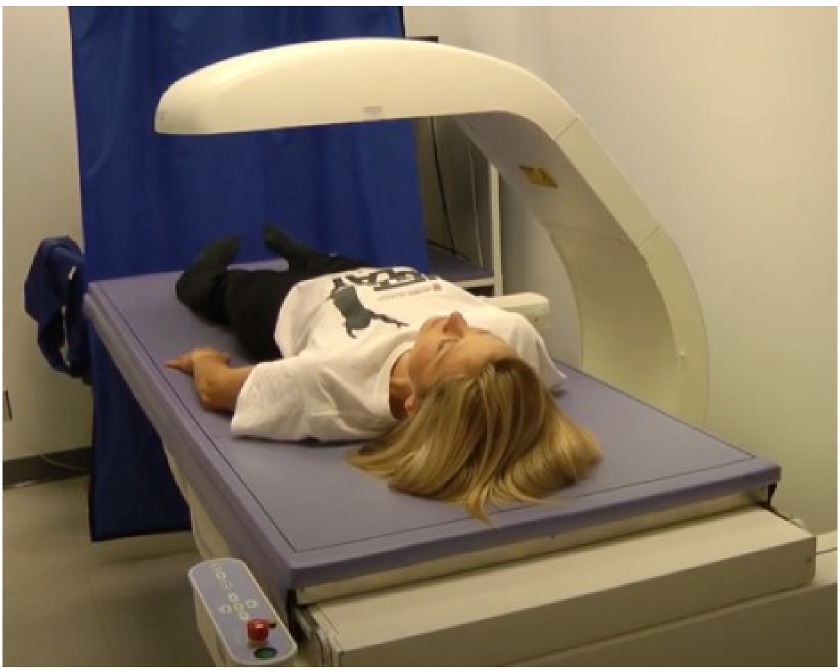
A recent model**: Lunar DPX-L** in which the two energies are produced using a cerium K-edge filter with a highly stable constant potential x-ray generator and tube. The tube is operated at 76kVp and the filtered beams have energies of 38keV and 70keV. Two tube current settings are available: 3mA and 0.75mA. The higher current is used to give faster scan times. Patients are scanned rectilinearly with the two energies measured simultaneously. (fast scan 3min)
The most common mode at this time was AP lumbar spine and femoral head.

The further development of these DPA and DXA machines included the use of fan beams instead of narrow pencil beams to reduce scanning time. [**The Lunar EXPERT** uses a fan beam and a solid-state array detector (48 discrete 0.8mm width photodiodes). The two energies are different from the DPX-L: x-ray-tube working at 134kVp 4mA and uses a tantalum K edge filter.
The x-ray detector, tube and generator are mounted on a motorised C-arm which can be rotated through 150 degrees for imaging different aspects of bones.]

Most recent Equipment:

Using "Comparison of two DXA systems: Hologic Horizon W and GE Lunar Prodigy, for assessing body composition in healthy Korean adults" Seung Shin Park et al in Endocrinol Metab (Seoul) 2021: 36; 1219-1231.

Conclusion: "Although measurements of body composition including muscle mass by the two DXA systems correlated strongly; significant differences were observed. But it is possible to link the systems with calibration equations.



Important references to demonstrate consistency between different equipment??
World definitions of osteoporosis based on these machines today.

Blake and Fogelman BJR 1997; 64:440. "Bone densitometry: current status and future prospects "
Mention of US as a possibility. This was written 28years ago but clearly states the direction that this work is taking and its potential value.

IAEA Human Health Series No 15 "Dual energy x-ray absorptiometry and body composition assessment" 2010

"Technical Principles of dual energy x-ray absorptiometry" G M Blake and I Fogelman. Seminars in Nuclear Medicine 1997;27(3):210-228

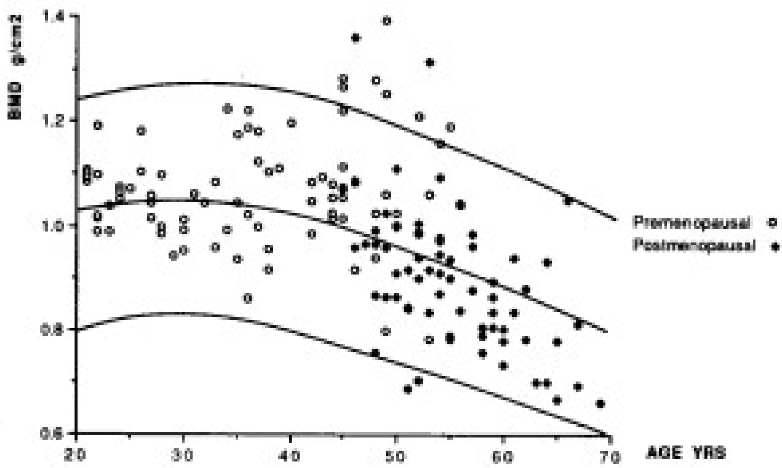


Figure 2. Comparison of US and UK data. The points are UK data and the curves represent US mean and two standard deviations.

Recent reference

"Updated practice guideline for dual-energy absorptiometry (DXA)". Riemer H J A Slart et al (International Working Group on DXA Best Practices European Journal of Nuclear medicine and Molecular Imaging 2025; 52:539-563

"Best practices for dual-energy X-ray absorptiometry measurement and reporting: International Society for Clinical Densitometry Guidance" E Michael Lewiecki et al (International Society for Clinical Densitometry. Journal of Clinical Densitometry 2016; 19:127-140

"Bone densitometry worldwide: a global survey by the ISCD and IOF "M A Clynes et al Osteoporos Int 2020; 31(09): 1779-1786
(ISCD International Society for Clinical Densitometry; IOF International Osteoporosis Foundation)

The importance of University Wisconsin in Madison.

John R Cameron 1922-2005, of Scottish heritage, he was born on a farm in northern Wisconsin. 1947 BS in maths at University Chicago. PhD in nuclear physics from University Wisconsin in Madison (where I visited in 1978??) At UW he worked in Dept. of Radiology where he applied physics principles to the diagnosis and treatment of disease. Founded a medical physics programme within a medical school.

Bone densitometry and TLD …also dealing with public concerns??? About low levels of radiation.
Soon after the Cameron paper, other researchers started to use similar methods…and different sites of the body.
Books: Medical physics: the physics of the body 1992 Madison Medical Physics Publishing. "Physics of the Body", JR Cameron, JG Skofronick, RM Grant, 2nd edition, 2017, Medical Physics Publishing.
Richard Mazess Worked under Cameron. He is founder of Bone Care and has been director of the Company since 1984. President and Director of The Lunar Corporation from 1974-August 2000. Now Professor Emeritus of Medical Physics at U W since 1985. [Another article: RB Mazess; JR Cameron, JA Sorenson: "Determining Body Composition by Radiation Absorption Spectrometry" 1970 in Nature 228,771-772, 1970].

Joint paper: "Precision and accuracy of bone mineral determination by direct photon absorptiometry", JR Cameron, RB Mazess and JA Sorensen, Investigative Radiology 1968; 3: 141

Abstract Quantitative computed tomography (CT) enables the measurement of biophysical processes characterized by morphology, composition, flow, and/or motion to aid in clinical diagnosis and intervention. Since its initial application for determining bone mineral density for skeletal fragility assessment, quantitative CT has continued to evolve alongside CT's technological advancements. A key challenge facing quantitative CT is the lack of standardization pertinent to image acquisition, reconstruction, and image analysis. With the introduction of spectral CT involving dual energy approaches and photon-counting detectors (PCD), we are now able to obtain detailed information regarding mass densities of endogenous and exogeneous materials. Furthermore, energy-resolved CT yields spectral image types (e.g., virtual monoenergetic image) that are, in principle, independent of tube potential and patient size. This paves the way for workflow standardization and helps improve the consistency and reproducibility of CT-derived measurements. In this article, we review clinical applications of quantitative CT, discuss key challenges associated with quantitative CT and its adoption into routine practice, and outline the unique benefits ushered by new CT technologies such as PCDCT towards improving quantitative imaging.

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