DEL MEDICAL

Long Length Imaging

History and evolution to modern, high-quality, accurate, cost-effective DR imaging

Long length imaging is a critical diagnostic study to examine measurement, alignment, and curvature in full spines and legs. The technique has grown with the widespread adoption of arthroplasty to assure correct alignment of implanted devices.

History of Long Length Imaging Techniques

Film

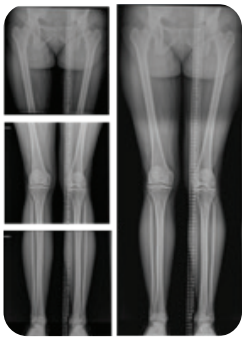
In the early days of film-based radiography, the largest standard size was 14 x 17 in (35 x 43 cm). To fit full spine or hip-to-ankle leg exams on film, exposures were made with multiple film cassettes. A Scanogram was often ordered to obtain measurements and diagnose the severity of leg length discrepancies. The Scanogram was typically performed by acquiring separate images of key anatomy on standard 14 x 17 in (35 x 43 cm) cassettes, with the patient in the supine position. The separate images taken of the pelvis, knee and ankle included a radiopaque ruler secured to the table between the lower limbs, for alignment measurements; however, if the patient moved between exposures, accurate measurements could be compromised.

Film screen cassette

Alternatively, multiple cassettes were overlapped, and a single exposure was used exposing multiple cassettes. Because the overlapped cassettes were a different distance from the x-ray source, magnification varied, creating measurement discrepancies. To improve this, a radiopaque ruler was placed in the imaging field behind the patient. Once the films were processed, they were visually aligned and often taped together. However, both methods had room for error in alignment and measurement. An improved film technique was created with a single 14 x 36 in (35 x 91 cm) cassette and film. This allowed a single exposure, with the film, either multiple sheets taped together after processing or a single large sheet, placed inside the long cassette in one plane. Such film was also made in "trifold" with small polyester hinges, to allow storage of films, folded, in a standard size film jacket.

Computed Radiography

With the emergence of digital imaging acquisition, Computed Radiography (CR) used a storage phosphor plate, read with a laser scan, to create a digital image. Initially, like film, the largest CR cassette size was 14 x 17 in (35 x 43 cm), and so long length imaging was not common. As demand grew to eliminate film, CR manufacturers developed techniques similar to those of long length imaging using analog film. Early CR methods first utilized overlapping cassettes (up to four) with total imaging size up to 17 x 52 in (43 x 132 cm) and CR readers used software to correct for varied magnification. The technologist inserted the cassettes into the CR reader, where the data was scanned and combined to make one long image. Second, a single phosphor plate up to 14 x 33 in (35 x 84 cm) evolved with various plate reader technologies to read the single large phosphor plate in parts and stitch the image into one. Such techniques produced accurate results, but full image display time was slow, sometimes several minutes, due to the scanning and reconstruction process.



Example of stitched images

CR 14 x 33 in cassette example

Current Technology and Issues with Various Methods

Digital Radiography

Digital Radiography (DR) showed promise to replace CR by directly creating a digital image from a DR detector. DR was rapidly adopted in the US, when 7% to 20% reimbursement penalties were placed on exams using CR or film technology. However, early manufacturing of DR faced significant challenges to make large detectors, and for many years, the largest plate available was 17 x 17 in (43 x 43 cm). As a result, imaging departments once again adopted different techniques for long length imaging.

- Keep film or CR

Some kept their CR, or even film, only for long length studies. This required departments to continue support and maintenance for CR readers and/or film processors and their cassettes for long length imaging exams alone.

- DR multi-exposure

As DR acquisition speed improved (from initial cycle times of 15-20 seconds down to 1-5 seconds), some used a single DR receptor which was repositioned for multiple images to cover the desired anatomy. DR's fast acquisition time also led to increased adoption of robotically positioned x-ray equipment. One purpose of such robotics was to automatically position the DR detector and move the x-ray beam for multiple exposures. In this technique, both rotational and parallel methods were explored. Most systems adopted the tube rotation technique. This geometric method kept the focal spot in a constant location while rotating the tube cephalic or caudal with the wall or table receptor tracking the central beam position. This method most closely mimicked the traditional film and CR exposures, where SID was longer at top and bottom, but constant in the middle, leading to smooth magnification and less distortion at the overlapping areas. Alternatively, the parallel method kept the tube and receptor parallel to each other. Both moved vertically or horizontally together with sufficient overlap of the same anatomy between each exposure. The parallel method was less sophisticated because it did not require the tube to be angled; still, the focal spot did not remain constant, causing increased distortion at the upper and lower edge of each image, increasing stitching difficulty.

One of the benefits of a fully automated x-ray room with auto positioning functionality is the ability to perform robotic stitching. The system determines the number of images required, image overlap, collimation, and system position based on the image area desired. It then uses sophisticated motorization to set the system position for each exposure automatically. Unfortunately, this type of system is often as much as 3 times the cost of a manual room, making it an expensive option if only needed for long length exams.

Overlapping DR detector example

Once all images were acquired, the DR software attempted to stitch the images together and display one long length image. Depending on detector readout speed and number of images required, the image acquisition process could take up to 40 seconds or more. The risk of patient motion increased the longer they were required to remain still, which made accurate automatic alignment of anatomy difficult. Despite the use of patient immobilization stands and barriers, motion between acquisitions remained a concern, especially for compromised patients. Another complexity of this method is the requirement for image blending. Multiple exposures are made with varying settings for the specific region of interest, commonly causing differences in densities between the various images. Software is used to blend density differences in the final image, but this can reduce fine detail in the overlapping areas.

• DR multi-detector

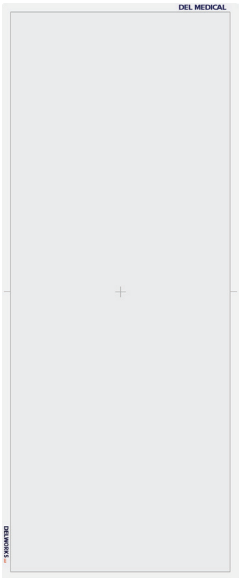
Initially, it was uncommon to use multiple DR detectors, due to a couple of issues:

- DR detectors were initially quite expensive
- DR detectors have electronics at the edges, and cannot be closely abutted, leading to a need to overlap detectors, like CR 17 x 52 in (43 x 132 cm) CR was overlapped. Software was required to subtract the detector edge electronics from the image. Such subtraction was difficult, and success depended on careful and consistent alignment and distance

As such, due to expense and complexity, multi-plate DR was initially not adopted. However, as the cost of DR detectors dropped and software advanced, overlapping multi-plate solutions emerged. These still relied on stitching line artifact reduction, but with the multiple plates permanently mounted in the panel, alignment issues were typically solved. However, this solution was large, heavy, and difficult to move from upright to supine or to use portably in surgery. Image display remained delayed due to the processing time required to correct magnification, minimize overlap artifacts, and stitch together data from individual detectors. Many such images still display some stitching line artifacts, but have at least solved issues with patient motion, based on using a single exposure.

DELWORKS LLI, the First Monolithic Long Length DR

In 2019, DEL MEDICAL launched DELWORKS LLI, the world's first monolithic (single piece) DR detector, with a large 17 x 42 in (43 x 107 cm) active area. This advanced technology enables single exposure imaging, eliminating the problems of motion artifacts, and eliminating overlap and stitching issues. As a single monolithic detector, it is a normal DR cassette detector thickness of 0.8 in (2 cm). It weighs only 24 pounds (11 kg), making it easy to position for upright, tabletop, or surgical imaging, and to move from room to room in busy orthopedic settings. Wireless technology and AED (automatic exposure detection) allow the detector to be easily used with any x-ray source, anywhere in the hospital for long length or routine exams. With single exposures ready for viewing in 9 seconds, it dramatically improves the speed of long length imaging. By using a single exposure, quality was dramatically improved, virtually eliminating motion artifacts and re-exposures, and yielding confidence in measurements. It reduces overall radiation dose requiring only one x-ray versus 2-5, and eliminates redundant exposure to patient anatomy in overlapping areas. The LLI prevents the need for repeat exposures due to patient motion, stitching failure, or insufficient overlap. It also enables dramatic productivity improvement, as difficult long length exams are conducted in essentially the same time as normal studies.



Cost-effective X-ray Automation: Robotics for Long Length Studies in the DEL MEDICAL OTC18S

In 2021, DEL MEDICAL solved the problem of the high cost of robotics in x-ray rooms used for long length imaging. Having heard the voices of many customers who said the only reason they needed robotics was for multi-exposure long length studies, DEL MEDICAL designed the OTC18S radiographic system, designed to automate multi-exposure long length imaging, using a standard size DR detector and multiple exposures. It adds motorized tube rotation and receptor motion to its already popular OTC18T radiographic system, which already includes vertical tracking. The OTC18S is ideal for the customer who wants robotics for a high volume of long length exams, but prefer the "grab and move" ease of a manually positioned system with tracking. It uses the popular tube rotation method for long length exams, to keep measurements and templating similar to previous methods with a single focal spot.

It provides automatic stitching of long length images after multiple exposures are automatically executed. By simply solving this most important reason for robotics, the OTC18S is much more cost-effective than other robotic, automated x-ray rooms. Both the LLI and OTC18S by DEL MEDICAL provide substantial advantages in quality and cost-effectiveness, and are the current state-of-the-art in high-quality long length imaging.

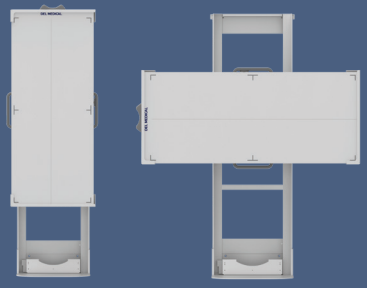
Other Factors to Consider in Long Length Imaging

SID and Room Layout

To obtain full coverage of the desired anatomy and detector, a Source Image Distance (SID) of 100 in (254 cm) is typically recommended. Layout of the x-ray room should be considered, and the use of a mobile upright stand is often desired. This long SID also helps to minimize varied magnification from top and bottom to center of the image. In supine and surgical exams, often the full SID cannot be achieved, and coverage is limited based on the longest SID that can be achieved. A weight bearing cap and pads are used for tabletop or floor use. In surgery, an articulating stand can allow the detector to be positioned under the cantilevered surgical table.

DEL MEDICAL offers two stands and a weight bearing cover to optimize positioning for a variety of uses of DELWORKS LLI

DELWORKS LLI Mobile Positioning Holder enables detector positioning for upright or supine exams, under a mobile or surgical table



DELWORKS LLI Mobile Vertical Holder for upright or cross table imaging

DELWORKS LLI Supine Panel Cover and provides up to 500 pounds of weight bearing capacity LLI Tabletop pads create a level and comfortable patient surface

In addition, workflow should be considered if the LLI is utilized in multiple rooms or in surgery. DEL MEDICAL offers both a desktop workstation and a tablet for LLI operation and image display, and the LLI detector may be used either wired or wirelessly for ultimate flexibility.

Grid

DELWORKS LLI uses a parallel grid, with focal distance from 44 inches to infinity, so that it may be used for routine studies with shorter SID or the longer SID of long length studies. It is built to size for full 17 x 42 in (43 x 107 cm) coverage and inserts into holders when needed to reduce scatter and assure optimal image quality.

Filters

Attenuation filters have been used for various radiography studies to improve visualization of soft tissue and bone detail on body parts with varying thicknesses for many years. Filters were commonly used in scoliosis or hip to ankle long length imaging in order to reduce x-ray penetration and potential for over-saturation in thin body parts (e.g. ankles and cervical spine) while allowing higher x-ray exposure to thicker parts (e.g. hips and lumbar spine). Film has a limited dynamic range, and filter use was often necessary to achieve correct density in all regions. CR and DR deliver increased dynamic range and ability to adjust image processing or window leveling to improve density differences, and with multi-exposure stitched exams, each exposure's generator settings can be adjusted, increasing technical complexity of the exam. While this often leads to abrupt density shifts in the image overlap area stitch lines, it delivers appropriate exposure in each region. With single shot CR and DR, filters are desirable. They dramatically cut exposure to thinner regions and deliver better image quality. While image quality may be acceptable without them, under ALARA principles, they are recommended.

Filters mount magnetically on the collimator, making them easy to use

Filter coverage area

Resultant optimized image

Applications Training

Crucial to the optimization of long length imaging exams is expert training. While DEL MEDICAL systems simplify and speed long length exams, DEL MEDICAL's expert Applications Specialists complete the package by training technologists to use the systems to their full potential for high quality, productive imaging.

Overall, DEL MEDICAL offers multiple methods of long length imaging, with the best technology monolithic plate for single shot, and the most cost-effective room for automated stitching, and accessories specifically designed to enable the highest quality, most productive long length examinations.

DEL MEDICAL

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New York
28 Calvert Street
Harrison, NY 10528
(Tel) 800.261.9808
(Fax) 914.835.6111

Illinois
241 Covington Drive
Bloomingdale, IL 60108
(Tel) 800.800.6006
(Fax) 847.288.7011

www.delmedical.com