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Digital Tomosynthesis on DR 800 and DR 600

A method for patient care and hospital productivity

White paper

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Table of contents

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Digital tomosynthesis – Extending conventional 2D X-ray imaging into the next dimension

Executive summary

Despite a large array of publications and clinically-oriented investigations and studies indicating potential applications in various fields, digital tomosynthesis (DTS) has not yet realized its potential as a widely used clinical application. Apart from mammography, where digital breast tomosynthesis (DBT) is becoming increasingly well-established, DTS is acknowledged in the academic field, but seemingly less in clinical practice – particularly not in productivity-oriented clinical environments. Agfa's tomosynthesis solution – facilitating novel reconstruction in combination with state-of-the-art MUSICA post-processing on both the DR 800 and DR 600* X-ray systems – allows Agfa to close this gap. By means of well-documented and practical clinical cases, this white paper demonstrates the potential of digital tomosynthesis in the radiological field. It shows that DTS can be a useful complement to 2D and CT imaging in improving department productivity and patient care.

In clinical practice, planar X-ray images are usually the first imaging technique used. For musculoskeletal imaging this can be, for example, a shoulder in AP and lateral projection. However, in many cases, this technique is not sufficient or adequately sensitive [1], and patients are referred to another imaging modality, such as CT or MRI, to facilitate further examination. In these cases, the final diagnosis cannot be achieved by X-ray imaging alone, resulting in additional waiting time and – in many cases – the need for new appointments. An imaging technique such as digital tomosynthesis, which allows immediate closure of the diagnostic cycle by providing the missing clinical information while the patient is being examined within the department, would be very desirable.

Adding value through an improved clinical pathway

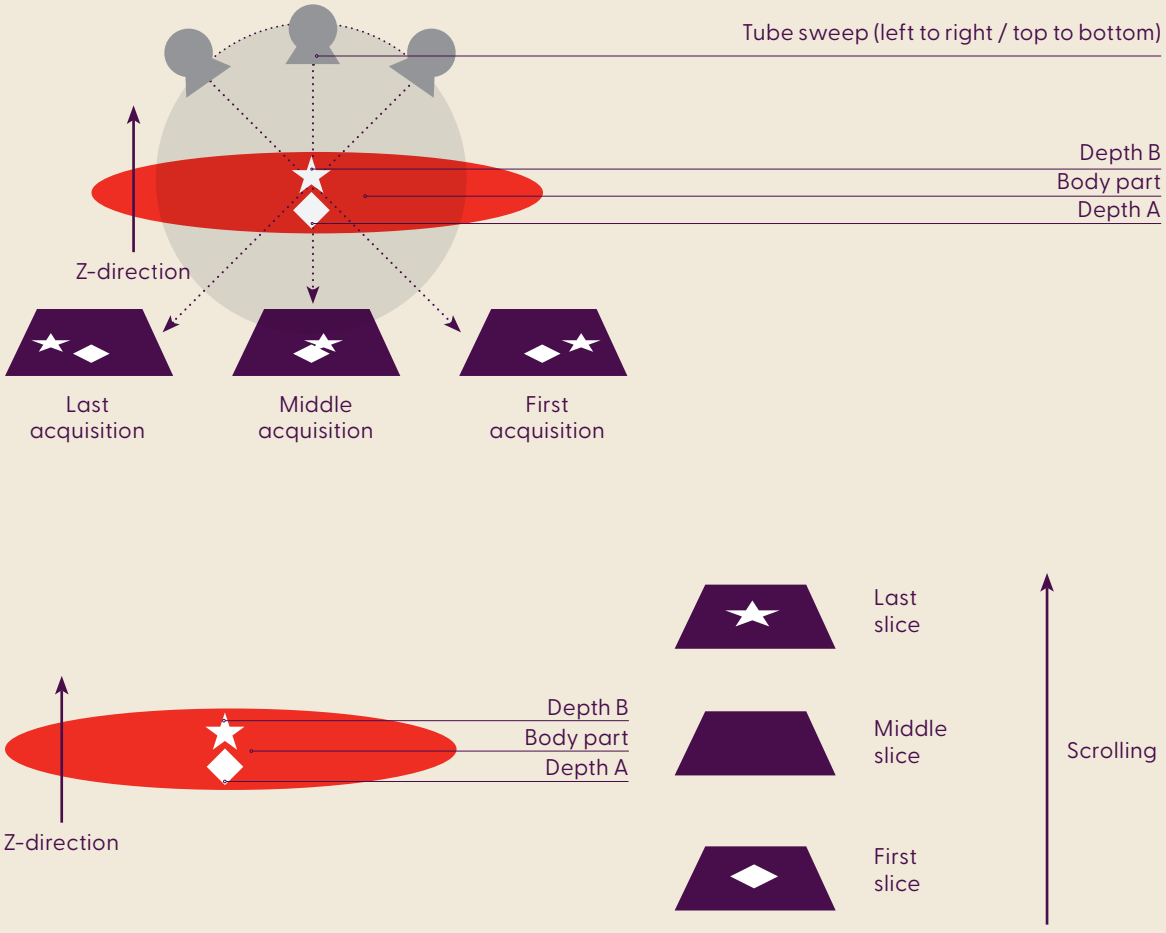
It is, therefore, worthwhile reconsidering the role and added value of digital tomosynthesis in general X-ray imaging, with respect to improving the clinical pathway. This is particularly relevant given the increasing importance of productivity gains – especially in mid-sized, productivity-oriented hospitals with limited access to and capacity for subsequent imaging exams (CT or MRI).

* DR 600 Tomosynthesis is pending 510(k) clearance in the US.

Digital tomosynthesis is an extension of one-directional 2D-projection radiography by a two-dimensional sweep adding information in one additional (z-) direction. DTS produces image slices through an object or body by using a direct digital (DR) imaging system with a digital semi-dynamic flat-panel detector. This is done by making a larger number (typically between 20 and 40) of low-dose image acquisitions across a range of projection angles of the X-ray tube, followed by a numeric reconstruction of the individual 2D projection images into plane image slices varying in vertical (z-) direction. The diagnostic reconstructed slices are postprocessed to obtain 2D-like image quality and appearance. DTS is, in this sense, an add-on imaging feature to commonly available DR systems.

The following scheme shows the reconstruction principle:

Fig. 1: Principle of tomosynthesis and reconstruction



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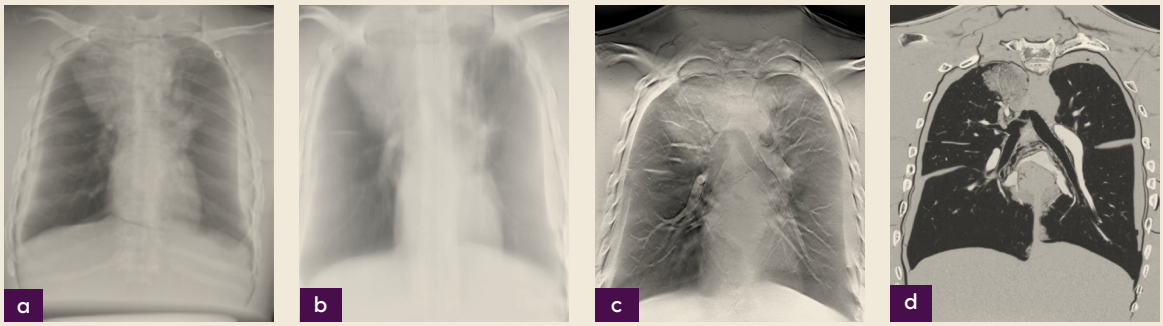
The primary purpose of DTS is to reduce the disrupting anatomical overlap in 2D X-ray projections by separating the 2D X-ray into different layers, without additional disruption from over- or underlying tissue.

Figures (a) to (d) illustrate the differences in image appearance between the three imaging modalities:

Fig. 2: Examples of X-ray based imaging: (a) PA X-ray, (b) classical tomography, (c) tomosynthesis image at the same depth position as (b), (d) coronal reformat of a CT exam, also at the same height position



Within Agfa's portfolio of DR systems, DTS is offered on the DR 800 and DR 600. Both systems facilitate either a full dynamic detector (DR 800) with a pixel size of 148 µm, or a semi-dynamic flat-panel detector (DR 600) with a pixel pitch of 148 µm. The frame rate is 6 and 5.2 frames per second, respectively. The exposures are performed using the same intuitively designed soft console (part of the MUSICA workstation) as the planar 2D X-ray exams, supported by a generator two-point technique. The typical duration of a sweep is between 5 and 10 seconds.

New options and variables

Tomosynthesis enables the selection of a small (15 degrees) or large (22 or 30 degrees) system-dependent sweep angle and a slice thickness between 2 and 9 mm. The start and end height can be set by the user for precise capturing of the targeted body part thickness. For the subsequent reconstruction (post-exposure) reconstruction, three quality levels are available (low - medium - high), each offering a difference in detail level and reconstruction time (ranging from 30 to 90 seconds).

From the MUSICA workstation, a new reconstruction with different height dimensions or slice thicknesses can be initiated from the same acquisition image set without re-exposure.

The final reconstructed slices are automatically processed with state-of-the-art MUSICA image processing software and transferred to the image archiving system for diagnosis, together with the 2D X-ray images. No scout image is taken. With respect to radiation exposure, doses for tomosynthesis exams (total dose per sweep) are pre-defined and configured on both the DR 800 and DR 600 solutions, and range from 5 to a maximum of 10 times the dose of the planar 2D X-ray (one view), with the potential for further dose reductions. This is still considerably lower than a corresponding CT scan, even when using low-dose CT protocols.

Authors of a recent publication [1] exemplify the radiation dose linked to tomosynthesis of, in this case, a wris (including coronal and sagittal acquisitions) as 25% less than a standard 5-view X-ray and 28 times less than a CT scan.

With the focus of this white paper on musculoskeletal applications – a main group of exams in mid-size and productivity-oriented hospitals [1] – a second advantage of DTS becomes obvious: the increased patient care.

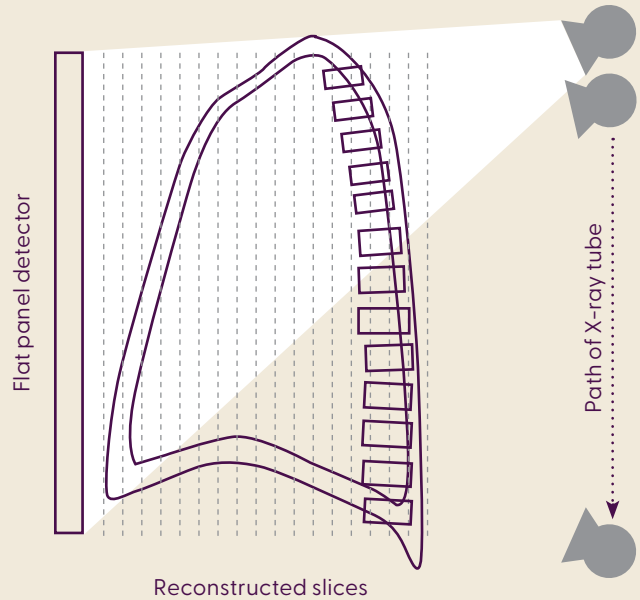
Removing overlying tissue and proper positioning of the patient can be extremely difficult, with bone fractures causing severe patient pain and restrictions in patient maneuverability. A second projection may be impossible due to the nature of the fracture, or additional X-rays from different angles may be necessary, requiring the patient to be repositioned or moved. With tomosynthesis immediately following an X-ray examination, the patient is already positioned and does not have to be repositioned or relocated to another modality. The necessary information to conclude the diagnosis can be obtained immediately and with minimum discomfort for the patient.

Thus, the value proposition of digital tomosynthesis is not based solely on the positive impact on departmental productivity resulting from the speed of obtaining clinical information, but also on the strong patient care arguments. Both together suggest the potential for a wider use in clinical practice than is currently the case.

Digital Tomosynthesis - why now?

Besides productivity and patient care benefits, the image quality of a DTS solution is crucial to its successful introduction and application. Agfa has developed a new reconstruction algorithm, which, together with the well-known and established MUSICA post-processing of the slices, provides optimal image quality to the end-user.

Fig. 3: Schematic of a tomosynthesis acquisition



The first step in tomosynthesis is the image acquisition: several X-ray projection images are acquired from different angles, as illustrated in Fig. 3. Next, a reconstruction algorithm computes the slices, parallel to the detector, as illustrated by the dashed lines.

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This reconstruction algorithm is the backbone of the tomosynthesis application. Not only does it significantly influence the noise and resolution of the final reconstruction images, it also has a substantial impact on the residual blur of out-of-plane structures. Typically, one-step reconstruction algorithms, such as the shift-andadd and Filtered Back Projection (FBP), are used. While these algorithms are fast, they suffer from noise and artifact contamination.

Agfa's reconstruction software employs an advanced iterative reconstruction algorithm, which repeatedly updates the reconstruction by comparing the acquisition images with simulated acquisition images based on the reconstruction images. The reconstruction images converge to deliver an optimal solution. This process is sped up by harnessing the parallel computing capability of the computer's graphics processing unit (GPU). The resulting reconstruction typically takes well under one minute.

Agfa's software also includes several image enhancement steps, developed to suppress tomosynthesisspecific artifacts.

In the final step, the reconstruction images are enhanced with Agfa's MUSICA image processing technology, which is based on Agfa's patented Multiscale Processing, offering greater detail and ensuring a consistent visualization. A dedicated tomosynthesis version of MUSICA has been developed to improve the look and feel of the reconstruction images.

Fig. 4: Advantages of MUSICA post-processing

without MUSICA

with MUSICA

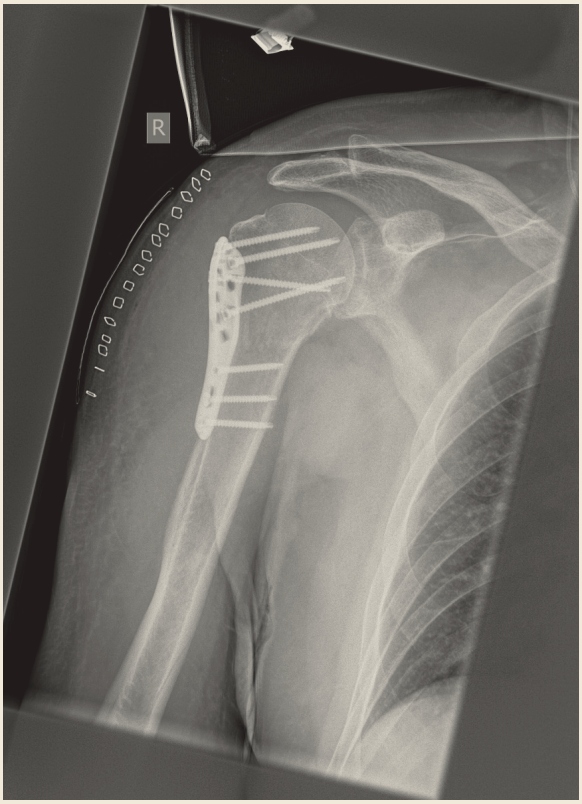
Clinical benefits

The following section provides several selected clinical cases, with a description of their clinical indication, the 2D projection as well as relevant DTS slice(s), and an explanation of the added value of DTS.

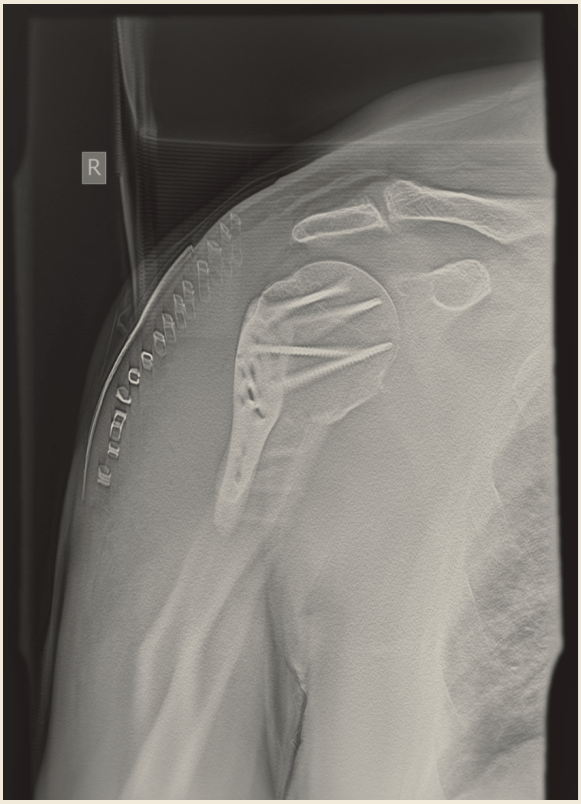
Clinical case 1:

Indication: 74-year-old patient with post-surgical control after osteosynthesis (i.e. orthopedic internal fixation) of the humeral head.

Fig. 5: DTS acquisition parameters: 70 kV, 46 mAs total, 39 slices, slice thickness 2 mm, reconstruction high



2D projection AP



DTS (slice 13)

Added value of tomosynthesis: good and sufficient positioning of the osteosynthetically supported fracture can be concluded with the humeral head and screws sharply delineated in the same image plane.

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Clinical case 2:

Indication: 73-year-old patient; determination of new vertebral fracture as possible cause of severe back pain.

Fig. 6: DTS acquisition parameters: 80 kV, 74 mAs total, 21 slices, slice thickness 2 mm, reconstruction high

2D projection lateral | DTS (slice 7) | CT reconstruction

Added value of tomosynthesis: newer BWK 8 fracture, visible through the vertebral cover plate, is diagnosed by tomosynthesis in the same way as it would be by CT. In addition, an older BWK 6 fracture is visible.

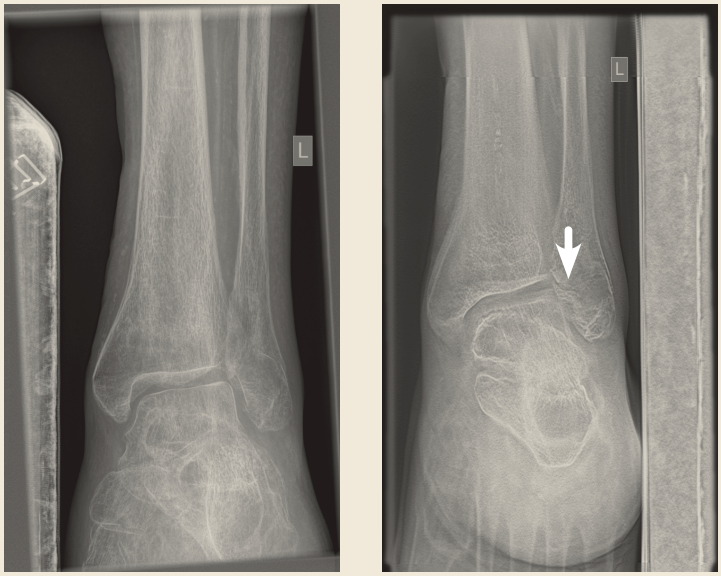
Clinical case 3:

Indication: 94-year-old patient; determination of a possible fracture (yes/no) after distortion of lower leg and ankle.

Added value of tomosynthesis: a Weber B-fracture, not oriented in the dorsal or ventral direction (and hence difficult or impossible to capture in an AP and lateral projection), becomes clearly visible.

The cases and examples outlined in this section indicate that in musculoskeletal radiography, specific clinical indications can be identified and grouped, as benefitting from DTS in addition to the standard 2D X-ray imaging, and prior to CT or MRI. These include indications such as determinations on post-surgical osteosynthesis of bones, new or existing vertebral fractures, and disangulated microfractures.

Fig. 7: DTS acquisition parameters: 60 kV, total 37 mAs, 13 slices total, slice thickness 2 mm, reconstruction high



2D projection | DTS (slice 17)

Productivity improvements

Besides the purely clinical aspect, both patient and hospital potentially benefit from using DTS under certain clinical indications immediately following the 2D projections. Assuming, for example, the duration of a standard 2D projection (AP and lateral) is 10 minutes, including patient positioning and starting and closing the exam on the modality workstation, the additional tomosynthesis sweep would add only a maximum of 5 minutes of radiographic operation. This is because virtually no patient repositioning is required, while starting a study, measuring the body part thickness, and performing the sweep can be done within a timeframe of 1 or 2 minutes.

Regarding patient care and diagnostic efficiency, DTS prolongs the exam time by an estimated 30% of the total time of the 2D X-ray. Furthermore, radiologists confirm that the additional time for reading the sequences on diagnostic workstations is negligible.

Conclusion: Digital tomosynthesis – A method for patient care and hospital productivity

Several musculoskeletal cases have been presented with indications, imaging examples (2D and DTS), and added value propositions of DTS. The latter include a shorter diagnostic cycle and significant improvement in patient care. These cases indicate that, requiring only limited extra effort (prolongation of 2D exam time) and a significantly lower X-ray dose (as compared to CT), a clear clinical benefit is achieved.

The main advantages (value proposition) of Agfa's digital tomosynthesis can be summarized as follows:

- **Improved triage**: final diagnosis is possible while the patient is still in the clinic, and waiting times for subsequent imaging modalities can be avoided.
- **Enhanced patient care**: little or no patient repositioning is required to obtain the necessary clinical information. Lateral projections, which are often painful for patients, can be avoided.
- **Lower radiation dose**: a significantly lower dose is required compared to CT, even low-dose CT.

Agfa's digital tomosynthesis solution delivers the opportunity for increased productivity and, at the same time, significant improvement in patient care.

More information on the Agfa DTS solution and the DR 800 and DR 600 systems can be found in the corresponding data sheets and marketing leaflets.

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Acknowledgement:

All clinical images are provided courtesy of Dr. D. Lommel, Radiologie Wittlich, Germany.

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