

CLINICAL PERSPECTIVES ON

Ingenia MR system





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INTRODUCTION

Imaging 2.0

The demand for MRI services continues to grow worldwide, mainly as a result of an increasing need for neurological studies and the early detection and treatment of malignant tumors, as well as the continued need to perform orthopedic examinations.^{1,2} In addition, there is an emerging requirement for MRI equipment to have a larger bore, due to increasing rates of obesity throughout the world.³ Hospital administrators are now faced with the constant pressure to improve productivity and keep healthcare costs down.⁴ In order to meet the growing demands for medical imaging services – while at the same time increasing efficiency and minimizing costs – radiology departments have a pressing need to find new ways to optimize imaging processes. They need to facilitate the integration of the various technologies involved in medical imaging, while improving the efficiency and ease of collaboration between radiologists and referring clinicians.

'Imaging 2.0' is a new concept in imaging technology, developed by Philips to enhance clinical integration and collaboration, and to achieve new levels of patient focus. Imaging 2.0 aims to remove the barriers that impede interactions between physicians and radiologists, enhancing the quality of care for patients. Providing a fully interfaced suite of imaging hardware and software solutions, it offers cost-effective, high-quality imaging that addresses the needs of radiologists and patients alike. Philips Ingenia MR is the first available digital broadband MR system and is an essential element in the Imaging 2.0 concept. It provides high-quality MR images, enhancing the physician's ability to arrive at a rapid and accurate diagnosis, and it improves the overall patient experience, using shorter scan/setup times and a comfortable environment, consisting of a wider bore and lighter coils.

Technological challenges in MRI

Improvements in MR imaging quality offer the potential for a more detailed understanding of the underlying pathological processes in many diseases. For example, small lesions that might otherwise be obscured at low resolution may be clearly visible at high resolution. In the pursuit of improved MR image quality, the current trend is toward using higher-strength magnetic fields.⁵ Increasing field strength correlates theoretically with improvements in signal-to-noise ratio (SNR), thus enhancing spatial resolution and improving image contrast.⁵ Higher field strength may also offer the added option of reducing scan times during data acquisition.

The use of high magnetic field imaging presents its own associated challenges. At high magnetic fields, the RF wavelength will decrease, approaching the physical dimensions of the human body. This effect can result in a reduction in B1 uniformity and consequent image distortion.⁵ Systems that incorporate multipoint parallel RF transmission have been proposed as a possible means to compensate for this effect, and therefore improve B1 homogeneity. Also, the increased RF power required during scanning to generate an RF pulse increases the specific absorption rate (SAR) in RF-rich scans such that care has to be taken not to overheat the tissue.⁵ An important means of dealing with this challenge is to use a parallel imaging tool, such as sensitivity encoding (SENSE).⁶ The incorporation of SENSE techniques contributes to echo train length reduction in RF-rich sequences, such as turbo spin echo (TSE), and in addition reduces image distortion in echo-planar imaging (EPI)-based sequences, including SE-EPI-diffusion-weighted imaging.^{7,8} However, this approach

has also required a substantial increase in both the number of receiving channels in the MRI system and of elements in the RF coils. The greater number of channels has yielded increased data rates and reconstruction performances. Consequently, MRI systems are having to support increasingly more channels, which has in turn required the introduction of additional receiving cables between coil elements and the MRI data acquisition systems. Although the SENSE technique has itself contributed to the improvement of overall image quality, the need for these analog cables – along with their bulky connectors and associated electronics – can actually deteriorate image quality, by making the MRI system especially sensitive to noise pickup.⁹

MRI applications are sometimes limited by the extended scan times required. A cardiac scan, for example, can require a patient to hold their breath for up to 20 seconds, which is often not feasible for a patient with a cardiac condition.¹⁰ The long data acquisition times are a result of the requirements of sequential gradient switching. With the powerful gradient coils available, excessive switching could potentially have a detrimental effect on the patient's electrophysiology.¹¹ The risk of incidental neural stimulation makes it impracticable to increase the speed of gradient encoding. The alternative encoding mechanism of SENSE, which utilizes multiple, simultaneously operated receiver coils, has the capability to circumvent such limitations. High-quality SENSE images in various fields of clinical practice have been acquired at 1.5T, including cardiac images, brain images, and images of renal and abdominal vasculature.¹¹ SENSE has had impact on cardiac imaging by reducing the required breath-hold interval and enhancing resolution.



Figure 1. Ingenia MR system.

AUTOMATED SNR-BASED COIL SELECTION: A STUDY

To address the need to visualize both large anatomic regions and small anatomic structures in a single examination, coils have been designed with a corresponding combination of larger and smaller elements. To obtain a detailed view of small regions of interest, however, this usually necessitates the manual selection or replacement of coil elements, which is not only a tedious chore, but also operator-dependent.

A recent study evaluated an automated SNR-based system of coil element selection, which was used to not only view the entire neurovascular tree, but also provide high-resolution imaging of the carotid artery vessel walls.¹⁷ The study included 5 male subjects (42 ± 6 years of age) who were scanned using a Philips Ingenia 3.0T system with a wide (70 cm) aperture and a prototype 62-element/channel neurovascular receive coil array with VGC gating. The coil was designed to cover the head (32 elements), neck and shoulders (6 elements), thoracic anterior region (16 elements), and carotid arteries (8 dedicated elements). The system had two independent RF transmission channels. Automatic coil element selection was based on the optimal local SNR.

Using a multi-stack, multi-chunk 3D time-of-flight (TOF) approach, the study showed that it was possible to visualize the entire neurovascular tree (from the aortic arch to the intracranial vessels) in less than 8 minutes, in all study participants. Targeted high-resolution carotid wall imaging was achieved in less than 7 minutes in all participants, with no operator intervention; it was evident that the local SNR in close proximity to the dedicated carotid coil elements was optimized. Furthermore, automated coil element selection was found to perform equally well as manual coil element selection.

In summary, the study demonstrated that a combination of a large number of elements and automatic optimal SNR-based coil element selection could efficiently meet the demand for spatial coverage as well as detailed imaging of a small region of interest.

Ingenia MR

The Ingenia MR system (Figure 1) does not have the limitations specific to analog scanners, due to its fully digital design. It is the first-ever digital broadband MR system and, as such, can provide improved image clarity and a better patient experience.¹²⁻¹⁴ The Ingenia system first became available in Europe, Canada, and Japan, and was available for sale in the USA in March 2011.

The 70 cm bore of the Ingenia MR system has a similar performance to a 60 cm system, yet allows larger patients to be scanned, and gives more comfort to every patient. Furthermore, fields of view (FOVs) of up to 55 cm can be used with high homogeneity, compared with the smaller FOVs of conventional smaller-bore systems. Moreover, the dStream architecture incorporated in both Ingenia 1.5T and Ingenia 3.0T systems can provide improvements in SNR, while allowing a streamlined and efficient workflow that is beneficial to both patients and healthcare providers.



Figure 2. Ingenia's DirectDigital miniaturized electronics that are fitted in the coil (in the technician's hand) replace the large electronics rack.

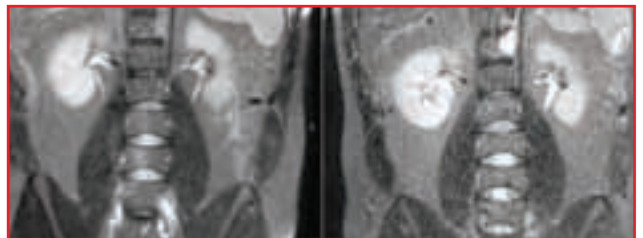


Figure 3. Ingenia 3.0T system showing up to 40% improvement in SNR with DirectDigital (left) and signal loss resulting from digitization performed away from the coil (right).

KEY FEATURES OF INGENIA MR

dStream architecture

The Ingenia 1.5T and 3.0T systems incorporate the dStream architecture, which encompasses a number of innovative technologies.^{15,16}

The DirectDigital technology, which is the first digital broadband MR system, was designed so that the signal is digitized directly in the receive coil closest to the patient during scanning (Figure 2). A digital signal can be transported by fiber optic cable, avoiding any signal loss and noise pickup that would be expected with traditional analog systems. DirectDigital RF has been shown to increase the SNR by up to 40%, and the improved SNR can result in sharper images at higher spatial resolution (Figure 3).

The FlexStream workflow of the Ingenia system allows simplified patient and coil handling. This improved efficiency results in fast examinations and a more rapid patient throughput, increasing productivity by up to 30%, compared with previous-generation systems.

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The EasyExpand feature means that the clinical capabilities of the Ingenia system can be expanded without the need for major hardware upgrades.^{15,16} Unlike traditional MR, for which upgrading from an 8- to a 16-channel RF coil required an upgrade to a 16-channel platform, Ingenia is channel-independent. Whatever the total number of elements in a coil, the system receives all data through a single broadband fiber optic cable.^{15,16}

FlexStream

FlexStream is a new concept in examination management and was designed to streamline workflow, increase flexibility, and reduce examination time. It utilizes FlexCoverage anterior and posterior coils and other different coil configurations, including head–neck–spine and torso coils, as well as FlexConnect connections, which enable single-handed coil connections and auto-eject for easy table undocking.¹⁵

Previously, if the initial survey scan showed that the planned image volume was outside the sensitivity reach of the coil, it was necessary for the technician to manually reposition the patient and the single coil (which has a limited coverage) relative to each other. This potential (and time-consuming) problem has been solved by the Ingenia system’s streamlined FlexStream workflow; its unique FlexCoverage posterior coil provides neck-to-toe coverage without the need for manual removal or repositioning. In other words, the spatial alignment between the image volume of interest and the coils is always correct, which is more convenient for both the patient and the technician, and allows for a high patient throughput.

FlexStream therefore allows imaging with fewer coils and may reduce the time needed for coil positioning and patient setup. Together, the simplified patient and coil handling help to speed up examinations, increasing productivity by as much as 30%.¹⁵

EasyExpand

Ingenia’s EasyExpand feature means that the clinical capabilities of Ingenia can be expanded without having to resort to system upgrades. In traditional analog MR systems, digitization was performed outside the RF coil. Each channel/element required its own analog coaxial cable, such that the number of RF channels was therefore a system specification. A system upgrade from an 8- to a 16-channel RF coil required an upgrade to a 16-channel platform.

CASE STUDY I

Whole-body diffusion-weighted oncology imaging: a first-hand account, from Professor T. Takahara (Guest Editor)

In our clinical whole-body MRI studies at the UMC Utrecht, Netherlands, we have started to scan our oncology patients with the new Ingenia 1.5T system. Keeping scan parameters of our regular sequences (T1-weighted, T2-weighted, and diffusion-weighted imaging [DWI]) similar, we were happily surprised by the image quality that Ingenia provided, compared with other platforms in our institution and those in collaborating institutions. Furthermore, thanks to the efficient design of the Ingenia system, including its coil setup, we are able to minimize table setup and dead scan times and, consequently, reduce total scan times and increase patient throughput. The features of Ingenia turn whole-body MRI into an examination that could soon be incorporated into regular clinical practice. The role of whole-body MRI in oncology may further be enhanced by the application of whole-body DWI, an important functional imaging method that is expected to be used for cancer screening, staging, and therapeutic monitoring. DWI with free-breathing acquisition is termed diffusion-weighted whole-body imaging with background signal suppression (DWIBS), and this concept is now widely applied to obtain a whole-body DWI examination that is well balanced in terms of scan time and image quality. The main limitation of DWIBS has been the relatively long scan time required. Previously, for example, 5–7 minutes of scan time was needed for 1 station of 24–30 cm, resulting in 20–28 minutes for 4 stations covering up to 120 cm for only DWI. Furthermore, DWI at 3.0T was believed to be inferior to that at 1.5T, because of the severe image distortion and nonhomogeneous signal.²² Ingenia, however, was able to overcome this limitation due to the higher number of dS SENSE factors that could be applied (up to 5 in a real scan setting). Consequently, image distortion is reduced, and even allows for direct coronal DWI scanning, which significantly reduces the scan time, owing to the reduced number of slices needed compared with standard axial DWI scanning. With coronal DWI scanning, 1 station can be acquired in just 2 minutes. This breakthrough is expected to increase the usage of whole-body DWI in clinical practice and to increase its popularity. Outside oncology, the considerable improvement of SNR also allows one to perform high-quality peripheral nerve imaging with DWI.

CASE STUDY 2

Difficult-to-scan patients – a patient with ankylosing spondylitis (Figure 4)



Figure 4. Kyphotic spine imaging.

Scanning of patients with certain conditions can present particular challenges and patient discomfort results in motion artifacts. In patients with spinal conditions, traditional MR systems are often unable to support the patient in a sufficiently comfortable position. The dStream HeadSpine coil has a head section that can be tilted by up to 20°, which offers comfortable support for patients with kyphosis. A case study investigated the use of the dStream HeadSpine coil in a 55-year-old male patient with ankylosing spondylitis who was evaluated due to a suspected transient ischemic attack.²³ The patient had presented with an episode of dizziness and blurred vision. Two possibilities were investigated by MRI: firstly, evidence of brain ischemia, or atherosclerosis of the carotid arteries or aortic arch, and secondly, abnormalities of the cervical spine. Due to the wide bore of the Ingenia 1.5T MR system and the tilttable head section, the patient was comfortably able to tolerate the scanning procedure.²³ No ischemia or atherosclerosis was evident, but multiple fused vertebrae were visible in the cervical spine.

Ingenia employs digitization within the coil, and each coil element has its own unique IP address. The data pass along a single broadband fiber optic cable. Expanding the clinical capabilities of Ingenia for use in other applications, such as cardiology or oncology, does not require a hardware upgrade. Any coil can be connected, however many elements it contains, maintaining flexibility and reducing lifecycle costs.¹⁵

A scalability study

The scalability of Ingenia's dStream architecture has been demonstrated in a recent clinical study.¹⁸ This study involved the acquisition of sagittal images of the whole neuro-axis (at 3.0T) with a resolution of 0.8 x 1.0 mm and slice thickness of 4 mm, together with a total FOV of 84 x 30 cm. Three volunteers were scanned, and no contrast agent was used.

The investigators were able to connect various coil sets with increasingly large numbers of elements. In one test, a total of 48 elements covering the head and whole spine were attached. In another test, a total of 74 elements were connected, covering the head, neck, and thoracic chest, including 2 specialist sections of 4 elements each on the cervical carotids. The investigators stated that, 'apart from the coils themselves ... no other modifications were made to the MR system.'

It was pointed out that a feature of the dStream architecture is that the multiple, directly digitized MR signals are optically transmitted from each coil to the reconstruction engine, and this architecture is independent of the number of elements. The investigators stated that 'since all coil control signals, e.g. tune, detune, diagnostics, etc., are also digitally communicated via the same fiber that transports the MR signal, adding and controlling additional elements, or even

'The Ingenia MR system has a 70 cm bore, and a large 55 cm homogenous FOV with design innovations that have avoided compromising image quality'

complete multi-element coils, can be done with no impact on the installed receive chain infrastructure and with a minimum number of optical connectors.'

Xtend image space

In the clinical setting, larger and obese patients are now routinely encountered. The first wide-bore MRI systems developed could accommodate larger patients but could not scan a large FOV.¹⁹ The Ingenia MR system has a 70 cm bore, which can accommodate obese patients, and a large 55 cm homogeneous FOV with design innovations that have avoided compromising image quality.¹⁹ Undergoing a scan is consequently more comfortable for patients while the high geometric fidelity increases the accuracy of image fusion/registration.¹²

The increase in bore diameter to 70 cm potentially has an impact on system power demand. The Xtend system makes use of wide-bore RF body coil design, taking advantage of the increased space available between the patient bore and the gradient coil inner diameter.¹⁹ This configuration results in an increased efficiency of translation of amplifier power into clinical gradient performance.¹⁹

Another innovative feature of Ingenia 3.0T is its MultiTransmit capability,²⁰ which reduces dielectric shading, using parallel RF transmission with multiple RF sources. RF signals are adapted to individual patients, maximizing the quality and consistency of images, even when performing real-time applications (Figure 5).²⁰ MultiTransmit provides improvements in image uniformity and consistency, while optimization of RF management confers time savings, with up to a 40% increase in scanning speed. The recently introduced MultiTransmit 4D capability has extended the potential application of 3.0T MR into areas such as cardiac imaging.²⁰

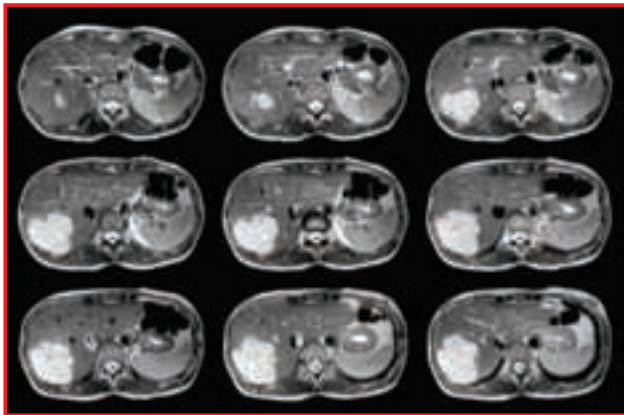


Figure 5. T2W TSE Singleshots with MultiTransmit.

Clinical acquisition of high-quality cardiac images at 3.0T

A recent study, presented at the ISMRM 2011 in Montreal, Canada,²¹ has demonstrated the potential of 3.0T cardiac MRI. The study investigated the capability of the Ingenia system to generate high-quality cardiac images in patients with a range of body types, using a 3.0T MRI system with RF shimming to image a region of interest (ROI). It included 8 healthy males and 3 healthy females (49 ± 16 years of age).²¹ A wide-aperture Philips 3.0T Ingenia system was used to generate B1 maps of an axial plane across the heart of each participant, using a saturation-recovery, dual-flip-angle method. B1 maps of an ROI circumscribing the heart with and without RF shimming were compared.

The authors of the study concluded: 'At 3.0T, even across as small a region as the heart, effective flip angles can be in excess of 20% of the prescribed flip angle in over 25% of the pixels without RF shimming.' RF shimming could effectively decrease the flip angle variation in the ROI. Previously, such a procedure would have been very difficult to perform, but the MultiTransmit capability of the Ingenia system enabled the acquisition of high-quality cardiac images at 3.0T.

CONCLUSION

As Ingenia continues to develop alongside the other imaging modalities encompassed by the Imaging 2.0 concept, the diagnostic capabilities of digital MRI will continue to expand. Ingenia MR is now routinely used in an increasing number of situations, including enterography and bowel imaging, fatty liver disease, breast imaging, advanced neurology, and musculoskeletal disorders. Areas of expansion for the future may include quantification of results, assessment of treatment response, and prediction of outcomes.

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