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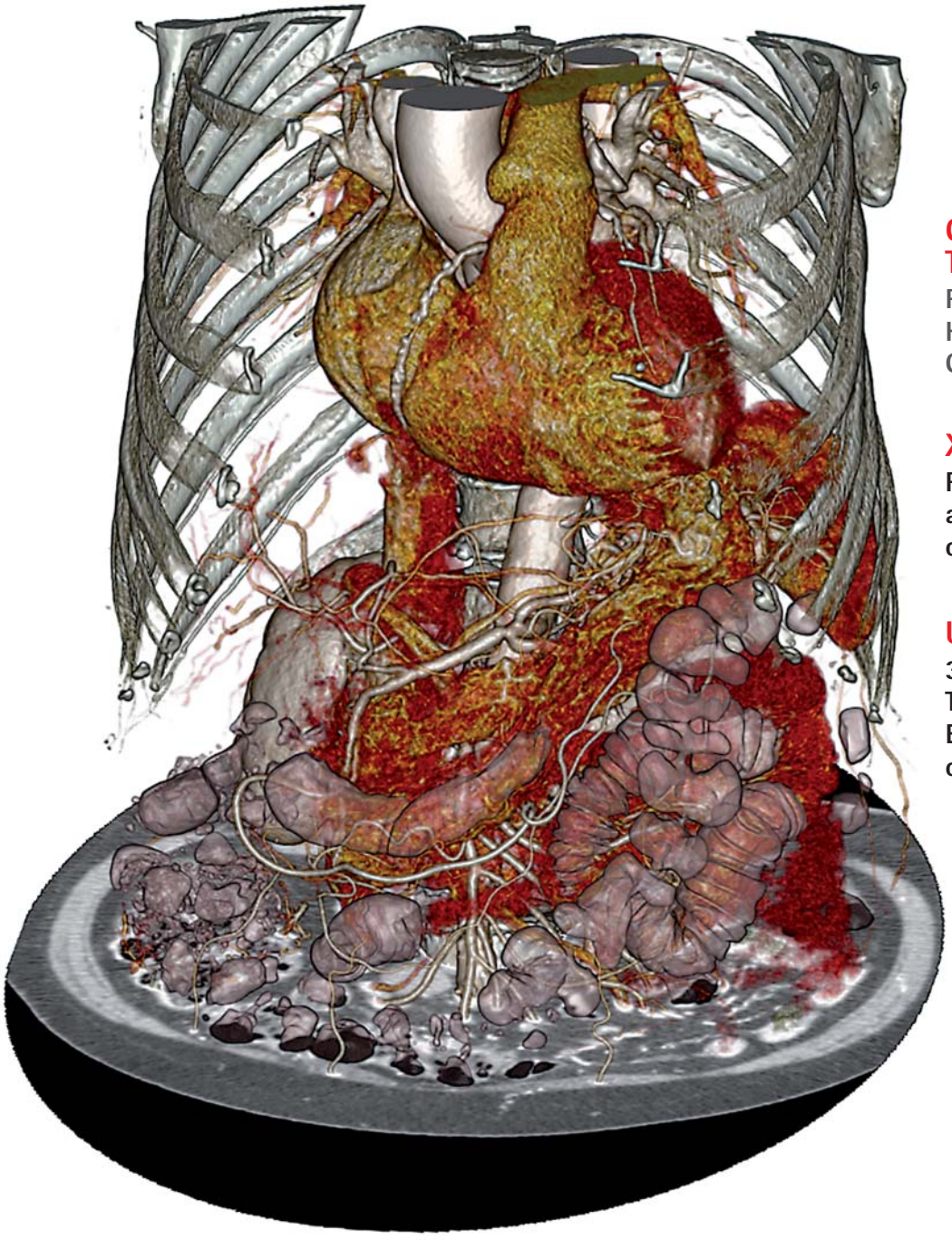
TOSHIBA MEDICAL SYSTEMS JOURNAL

TOSHIBA

Leading Innovation



## Computed Tomography

Prospective ECG-gated Helical 64-Detector Computed Tomography

## X-Ray

Rotational Cardiac DA and the Advantages of the Angio Lab

## Ultrasound

3D Wall Motion Tracking and Elastography of the Prostate

# VISIONS

14·2009

*Combined MPR and 3D reconstruction of heart and abdomen. Made by Toshiba's Aquilion ONE console software*

TOSHIBA MEDICAL SYSTEMS

**Imprint**

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# Dear reader,

Heart for Innovation is the theme that Toshiba has chosen for the 2009 ESC congress in Barcelona. And with good reason: Toshiba is an innovator to the backbone.

Already from the early days, Toshiba has worked to improve the quality of life for all people. The company's technology, from light bulbs to laptops, has delivered on this promise with medical innovations that are Made for Life — made to improve the lives of patients, clinicians and administrators.

This legacy is expressed best in the partnership of Toshiba's founding companies: Tokyo Electric Company and Shibaura Engineering. These two companies' life-saving partnership (now Toshiba) developed one of the world's first X-ray machines in 1932 to help physicians manage a tuberculosis outbreak in Japan. Today, Toshiba's imaging technology continues to save lives and improve the health of people around the world with some of the most powerful and patient-friendly systems available.

Focussing on cardiology, Toshiba has become a leader in technological innovations that continiously improve medical healthcare. Examples are the world's first Dynamic Volume CT scanner – the Aquilion ONE – a quantum leap that will carry cardiac CT imaging to the next level.
Or – in ultrasound – the Artida that provides unprecedented image quality, ultra-fast and straightforward 4D volume navigation and advanced wall motion assessment.
New technologies such as rotational DA in X-ray offer substantial dose reduction coupled with reduction in contrast media. Or the complete suite of contrast-free MRA techniques that offers image quality that is as good as – or sometimes even better than – images acquired using gadolinium-based agents in MRI.

This edition of VISIONS magazine is published and distributed during Europe's largest cardiology congress: ESC 2009. Toshiba's participation in this congress starts with the two symposia on Saturday and with a booth (#A499) near the Poster Area in the Exhibition Hall.
I wish that ESC will bring you a lot of opportunities to acquire new knowledge, exchange ideas and get up-to-date information in the field of cardiology and diagnostic imaging. Looking forward to seeing you at our booth any of the days and showing you our Heart for Innovation.

Kind regards,

**Jack Hoogendoorn**
Sr. Manager Marketing Communications
Toshiba Medical Systems Europe BV

TOSHIBA

Leading Innovation

STANDBYOU

ready to act

# Always by your side

At Toshiba Medical Systems, we focus exclusively on advanced diagnostic imaging. That's why our CT, MR, X-ray and Ultrasound systems lead the field. All of them are backed up by a global service network that's ready to act whenever you need support.

Standbyou is our full-service concept that maximizes your system's performance and availability. From a basic level option to an all-inclusive solution, each delivers the benefits of a service organization close by you. A highly trained team of professionals is at your disposal whenever you need them. Regular maintenance visits ensure superb diagnostic images and help get the most out of your system. And discounts on corrective maintenance, labour and spare parts minimize your financial burden. In short, Standbyou offers peace of mind. For your people, your patients and above all you.

Toshiba: Made for Patients, Made for You, Made for Life!

Made for Life™

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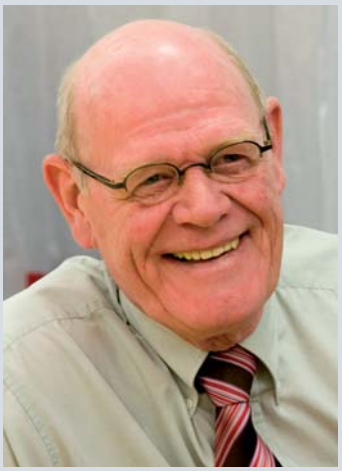
ULTRASOUND CT MRI X-RAY SERVICES

**„Our goal is to enable people to live rich lifestyles in harmony with the earth by making a positive contribution towards a safer, more comfortable and more productive life for everyone..."**
**Interview with Hans van der Veer about environmental challenges for Toshiba Medical Systems.** **Page 6**




**The Infinix-i series combines superb image quality, unparalleled range of access for clinicians and comprehensive dose management features to ensure clinical imaging procedures that are fast, safe and precise.** **Page 12**

# Toshiba Medical Systems – Acting Responsibly for Society and the Environment

**Toshiba is thoroughly committed to environmental protection. It has a solid policy which aligns its business with the environment and improves the quality of life of the global society. VISIONS finds out just how much the environment is incorporated into the daily work by talking to Hans van der Veer, Senior Manager of Regulatory Affairs and Quality Assurance at Toshiba Medical Systems Europe.**

**VISIONS:** *Why is Toshiba Medical Systems Europe concerned with the environment?*

**Hans van der Veer:** Business is the primary agent driving globalization. It can help ensure that markets, commerce, technology and finance advance in ways that benefit economies and societies everywhere and contribute towards a more sustainable and inclusive global economy.

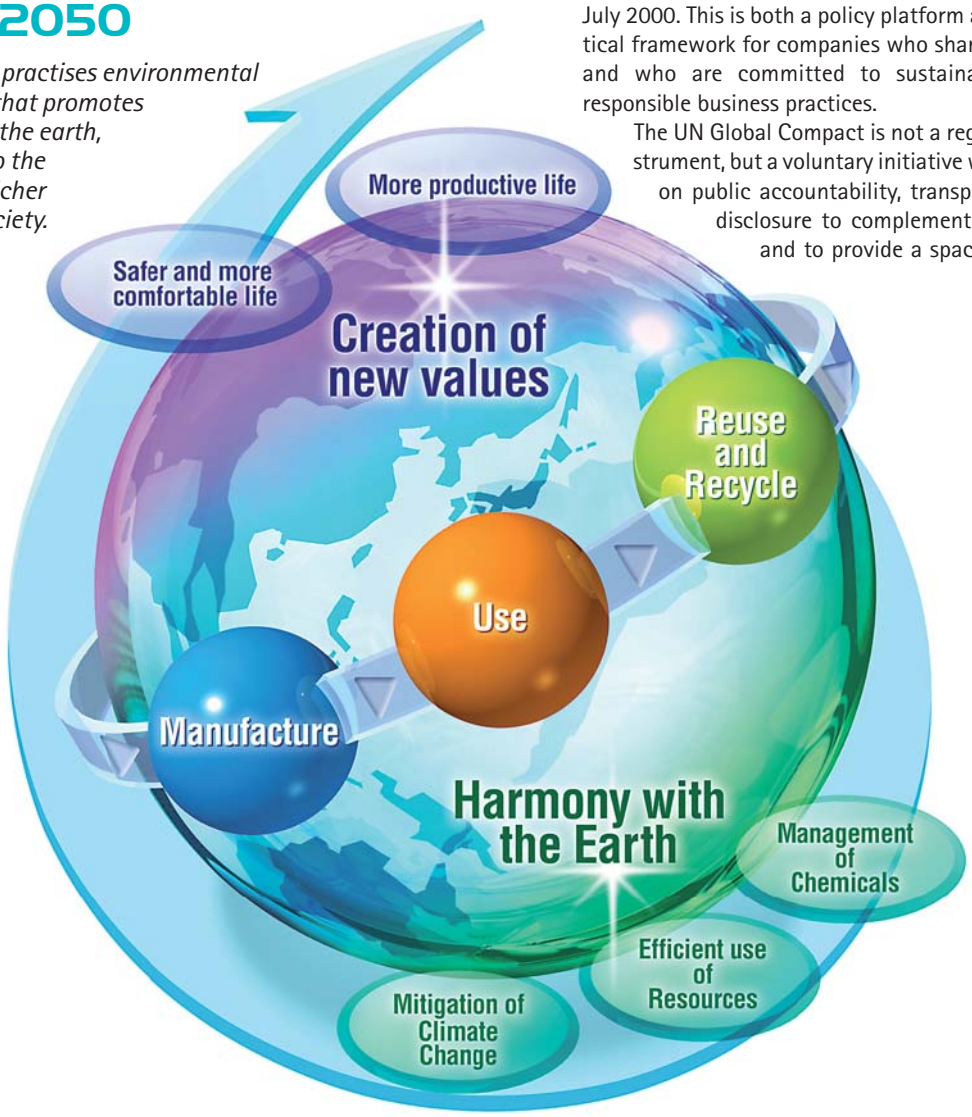
Toshiba Medical Systems Europe, just as Toshiba Corporation, strongly believes that it has an integral responsibility as a corporate citizen to contribute positively to society and the environment.

The inspiration for Toshiba's work in this area is the United Nation's Global Compact, launched in July 2000. This is both a policy platform and a practical framework for companies who share this view and who are committed to sustainability and responsible business practices.

The UN Global Compact is not a regulatory instrument, but a voluntary initiative which relies on public accountability, transparency and disclosure to complement regulation and to provide a space for inno-

## Environmental Vision 2050

*Toshiba Group practises environmental management that promotes harmony with the earth, contributing to the creation of a richer lifestyle for society.*



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vation. It seeks to align business operations and strategies everywhere with ten universally accepted principles in the areas of human rights, labour, environment and anti-corruption.

Our goal is to enable people to live rich lifestyles in harmony with the earth by making a positive contribution towards a safer, more comfortable and more productive life for everyone, to foster close relationships which are rooted in trust and respect, with customers, business partners and communities around the world and to help protect the global environment.

*"**Our goal** is to enable people to live rich lifestyles in harmony with the earth by making a positive contribution towards a safer, more comfortable and more productive life for everyone..."*

**VISIONS:** *What are the challenges?*

**Hans van der Veer:** The challenges are significant – as the world's population grows, our activities are changing the environment at an alarming rate.

According to the Intergovernmental Panel on Climate Change (IPCC) man-made greenhouse gas emissions are increasing average global temperatures and changing the climate.

Global concentrations of the main greenhouse gases, carbon dioxide ($CO_2$), methane and nitrous oxide, have increased significantly as a result of human activities and now far exceed pre-industrial values. $CO_2$ is considered to be the most important man-made greenhouse gas.

To mitigate climate change, it is generally accepted that it will be necessary to reduce the concentration of $CO_2$ and other greenhouse gases in the atmosphere. This requires substantial reductions in global emissions over the coming decades.

All countries will have to be part of this process, with developed countries taking the lead. Innovation and technology will have a vital role to play in reducing greenhouse gas emissions.

Toshiba has embraced these key environmental challenges and is committed to finding solutions. Our priorities are to reduce the environmental impacts of population and economic growth and to create rich value.

**VISIONS:** *When did the environment become an important element of your business?*

**Hans van der Veer:** Toshiba Medical Systems Corporation became involved in a major way with environmentally-conscious activities more than thirty years ago, when its new factory in Nasu, Japan, was designed in an eco-friendly way.

In particular, water quality was of great concern to Toshiba in developing plans for the facility. A biological treatment and purification system was specially designed to return water used in the manufacturing process in a state better than the level required by regulations. More modern processing technology was used from 2003. In a pond between this water treatment system and final river sluice, Koi carp thrives, symbolising the inextricable connection between the environment and industry.

Since 1978, the scope of activities and control over environmental management was expanded to include:

1. Set-up and continuous enhancement of the environmental management system
2. Introduction of Voluntary Environmental Plans (exceeding regulatory requirements)
3. The creation of eco-friendly products
4. Business activities considering environmental impacts and risk reduction
5. Environmental communication.

Gradually, our national sales organisations have become required to contribute towards increasing environmental awareness and implementing performance improvements.

Progress is checked by internal audits.

**VISIONS:** *What is Toshiba's approach?*

**Hans van der Veer:** Toshiba has adopted an exceptionally long-term, target-based approach to solving environmental issues. People leading rich lifestyles in harmony with the earth — this is the ideal situation envisaged in 2050 according to the Toshiba Group Environmental Vision 2050.



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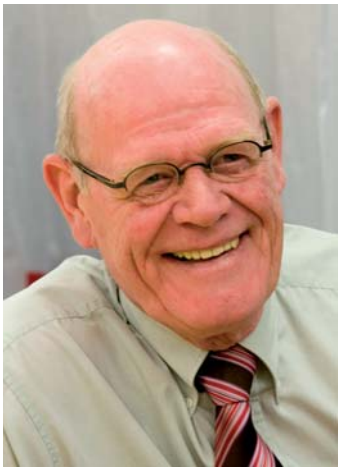


## "The responsibility
*for the environment lies with each and everyone of us."*

Toshiba aims to make the vision a reality by pursuing two complementary approaches: while the Energy Approach emphasizes the stable supply of reliable energy and mitigation of climate change, the Eco Products Approach focuses on creating new value in harmony with the earth. In addition, we are taking action on two standpoints – while Eco Process seeks to minimize environmental impacts throughout business processes, Eco Program is a concerted effort to tackle environmental issues in collaboration with our stakeholders.

The results of these efforts are expressed as Eco-Efficiency. The target for 2050 is to improve by a factor 10 compared to the year 2000.

**Factor T consists of two elements:**
environmental impact and product value. It should be realised that the environmental impact of a product is not only determined by its energy consumption and use of materials. Product value, such as improved functionality, also has an important effect on the environmental aspects.

Toshiba Group has devised a unique eco-efficiency indicator - Factor T.

This "factor" indicates the degree of improvement of eco-efficiency and is applied to every product made by Toshiba. Toshiba comprehensively evaluates not only greenhouse gases, such as $CO_2$, but also various kinds of environmental impacts generated from resource consumption (e.g. metals, plastics, energy), and waste disposals throughout the life cycle of products.

**VISIONS:** *Who is responsible for implementing the environmental policy?*
**Hans van der Veer:** The responsibility for the environment lies with each and everyone of us. From adhering to specific environmental regulations, to incorporating environmentally-friendly features into design of a product, to saving energy in the office – we all have a role to play. However, there is also a robust corporate structure at Toshiba which guides and monitors environmental performance globally.

Environmental management is promoted throughout all Toshiba's companies.

Within its corporate structure, countermeasures for problems concerning environmental issues in management, technological development, production and sales are proposed, discussions on transforming the "Environmental Vision" into a "Voluntary Environment Plan" are conducted, the orientation of activities is determined and the status of progress is checked.

The process involves experts in every field of environmental management.

Regional environmental management conferences are held to determine the orientation of its activities.

Toshiba implements a comprehensive auditing system to monitor progress within this system.

**VISIONS:** *What role does innovation play in environmental policy?*
**Hans van der Veer:** Innovation is critical to reaching our targets. Environmental issues are critical, right from initial R&D, at the very start of a products life cycle and right through its manufacture, use, service and eventual disposal. In all areas, major and continual improvements are only possible with the help of innovation. Improving existing technologies is not sufficient!

Toshiba recognizes innovative environmentally-conscious products (ECP) with a yearly award for excellence. Products are assessed on three viewpoints: design, evaluation and indication of "best practice".

In 2008, Toshiba Medical Systems Aquilion ONE CT was selected as one of Toshiba's top excellent ECPs.

The product was developed by applying an innovative technology from different industry segments. The system features the reuse of power generated when gantry rotation is stopped. Together with various other innovative applications, power consumption in the Aquilion ONE is reduced to less than one quarter per patient examination.

**VISIONS:** *What are our goals for the future?*
**Hans van der Veer:** Towards achieving the Toshiba clear targets for reducing $CO_2$ emissions, Toshiba Medical Systems has identified clear areas for improvement in product development. The main design focus for medical products in the coming years is on; reduction of power consumption during use, abolishment of potentially hazardous substances and reduction of weight (using less resources). Detailed targets are set for each aspect.

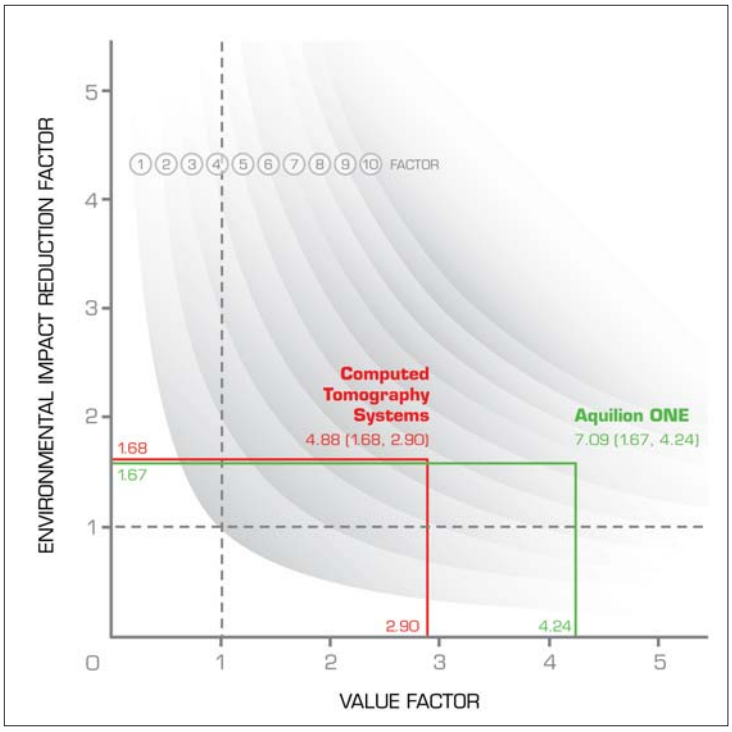
**VISIONS:** *How are the targets monitored?*
**Hans van der Veer:** Monitoring the realisation of targets is done continually. At least once a year targets are reviewed and adjusted where appropriate.

In addition, the environmental performance of the national sales organisations is also monitored.

Every quarter each organisation is required to submit related data that is included in the Toshiba Medical Systems Corporation annual environmental report. This is available to the public as well as internally.

**VISIONS:** *What are the achievements so far?*
**Hans van der Veer:** Based on the Energy Approach, it is estimated that Toshiba reduced $CO_2$ emissions by 2.76 million tons in fiscal year 2007.

At product level, environmentally conscious products are now a priority in development. As a result, 15 (hazardous) substances have been, or are being abolished.




"**Monitoring**
*the realisation of targets is done continually. At least once a year targets are reviewed and adjusted where appropriate."*

In business processes, there has been a significant $CO_2$ reduction in production processes whilst waste has been reduced by employing an improved recycling rate. In chemicals management, there are significant reductions in emissions in air and water.

**VISIONS:** *What role do EU environmental regulations play?*
**Hans van der Veer:** An important part of our work is keeping ahead of change in regulations in each country and making sure our processes adhere to the requirements - and exceed them). An added complication in this respect is that implementation of EU Directives may vary per country.

The European Union is one of the most advanced regulatory environments in the world. At present, there are four major legislative instruments which guide our current work.

**The Waste Electrical and Electronic Equipment Directive (WEEE Directive)** *restricts the use of hazardous substances in electrical and electric equipment and promotes the collection and recycling of such equipment.*

*This mainly affects Toshiba Medical Systems Europe operations. Administrative processes have been set up to meet national requirements. This can range from reporting of commercial and logistic activities to national authorities, to physical dismantling and/or collection of a product at the end of its life cycle. Administration and reporting of scrapped goods must also be covered.*

**The Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS).**
*This Directive aims to abolish the use of hazardous materials. Its impact is mostly on the design of products. For any substances due to be banned, alternatives must be found or, where not possible, exemptions must be applied for.*

**The Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).** *This Directive aims to give a clear insight into which chemicals or substances constitute different products. Toshiba Medical Systems Europe must comply with restrictions on design and manufacturing and distribute information about specific hazardous substances that may be included in its products.*

**The Batteries Directive regulates the manufacture and disposal of batteries in the EU.**
*This has implications for both design and operations at Toshiba Medical Systems Europe. Design must take into account that certain types of batteries are banned and the our operations must report to authorities in each EU Member State which and how many batteries are incorporated in the products placed on the market over a given period.*

These regulations have far-reaching implications throughout our business. Firstly, they highlight the regulatory importance of environmental compliance. Secondly, they drive individual companies towards prioritizing environmental actions, activities and achievements. Not only manufacturers, but also their sales companies. The increased number of environment-related questions in tenders are evidence of growing awareness. It can be said that the environmental achievements of a company are becoming part of the purchasing decision process, which inevitably acts as a catalyst for further environmental improvements.

In the light of these developments, it is important that all our employees understand the background of the instruments, appreciate the long-term goals that they are designed to achieve and are furthermore aware of market developments. An important part of my job is to foster a positive attitude towards these changing requirements.

**VISIONS:** *How is Toshiba working with other companies in developing environmental policy?*
**Hans van der Veer:** Toshiba Medical Systems Corporation participates in several industry bodies across the globe, facilitating the exchange of information between companies and helping to shape future environmental policies.

In Europe, we are an active member of COCIR, the European Association of Medical Device Manufacturers. Under this umbrella, new environmental regulatory developments are reviewed. This organisation is also a platform for discussions and exchange of views with EU regulators.

**VISIONS:** *Where can readers find out more about the environmental work of Toshiba?*
**Hans van der Veer:** Toshiba companies have special website sections dedicated to corporate social responsibility - CSR - and the environment. Here readers can find many resources which explain in depth our philosophy, current projects, targets and achievements[1].

1 Reference:
Toshiba Corporation Environmental website:
http://www.toshiba.co.jp/env/en/index.htm

TMSE Environmental website:
http://www.toshiba-medical.eu/en/QUICKLINKS-Repository/HOME-QuickLinks/Environment/

**For specific information visit:**
Toshiba Corporate CSR Report
http://www.toshiba.co.jp/csr/en/report/index.htm

Toshiba Corporate Environment Report 2008
Leaflet on Factor-T
http://www.toshiba.co.jp/env/en/report/index.htm

Toshiba Medical Systems Corporation reports
http://www.toshiba-medical.co.jp/tmd/english/corporate/index.html



GNEU09002

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# New handset TG01 from Toshiba – mobile connectivity at any time and everywhere


**This summer, mobile communication reaches a new level across Europe: With the TG01 Toshiba launches a mobile handset that promises to offer twice the processing power, more advanced multimedia, and a much thinner shape than today's smartphones.**

*"I am thrilled to announce the launch of TG01 in Europe, the market that we position at the center of our digital products strategy,"* said Hisatsugu Nonaka, Corporate Senior Executive Vice President of Toshiba Corporation during the product presentation at the Mobile World Congress in Barcelona eralier this year. *"Our challenge was to provide an innovative product that goes beyond today's needs to anticipate tomorrow's capabilities. In creating the TG01, we've integrated the very best of our mobile and LCD technologies in an attractive, premium quality multimedia handset with internet access capabilities. TG01 represents Toshiba's commitment to excellence in an exciting new category, and we look forward to launching it in the global market."*

Featuring an enormous 4.1"* Wide-VGA (800 x 480) touch-screen display, the handset profits from Toshiba's expertise in the LCD TV sector, whose technology was adopted for the TG 01: Using advanced picture-definition technologies taken directly from the company's acclaimed range of LCD TVs, the TG01 delivers greater colour image control, ensuring that the display is bright and vivid, with pin-sharp processing for fast-moving video playback.

Moreover Toshiba's TG01 is the world's first mobile device with Qualcomm's Snapdragon™ chipset. Snapdragon uses a custom processor design to deliver an industry-leading combination of 1 GHz computing and high-power efficiency. By offering processing performance, immersive multimedia, built-in GPS, and high-speed 3G connectivity integrated into a single chip, Snapdragon enables the TG01 to be a groundbreaking, super slim device that is immensely powerful.

Built around Windows Mobile®, the TG01 supports multimedia and web content as well as work efficiently. Featuring Internet Explorer® Mobile, the TG01 delivers a mobile browsing experience on par with what you'd expect from a desktop computer, with support for even the most graphically rich web sites and the ability to easily complete web transactions, such as banking or social networking site updates. With Microsoft Office Outlook® Mobile it's also easy to manage your personal and professional e-mail, as well as contacts and calendar. *"Windows phones bring customers closer to the people and information they care about, whether they are communicating by phone, e-mail or through instant messaging," said Andrew Lees, Senior Vice President, Mobile Communications Business at Microsoft Corp.*

## Just shake it!

Innovative gesture operations also make it easy to carry out everyday tasks without even touching the screen – a simple shake when the device is ringing, for instance, will automatically activate an incoming call, while an integrated tilt sensor allows users to switch between open applications just by tilting the device to the left or right. Also coupling with floating touch pod and zooming bar makes TG01's one hand operation easier, and being 9.9 mm* thin makes sure it can fit into a slim pocket unnoticed – packing more technology into less space than before.

## Product details

Toshiba's TG01 will be available in two colours, with consumers able to choose from a subtle deep black or a vivid white. Pricing and network availability will be confirmed at a later date.

### SPECIFICATION OVERVIEW

| | |
|---|---|
| **Size:** | 70mm x 129mm x 9.9 mm* |
| **Weight:** | 129 g |
| **Display:** | Wide-VGA (800 x 480), 4.1"* |
| **Camera:** | 3.2 mega-pixel, autofocus |
| **Memory:** | 512 MB ROM / 256MB RAM, micro SDHC slot up to 32 GB |
| **Interface:** | Bluetooth v2.0, USB v2.0, Wi-Fi 802.11 b/g |
| **Battery:** | 1,000 mAh, Standby: up to 11 days, Talktime: up to 5 hours (GSM)** |
| **Band:** | 850/900/1800/1900 for GSM/ GPRS/ EDGE, 2100 for UMTS/ HSDPA (7.2 Mbps)/ HSUPA (2 Mbps) |
| **Navigation:** | Built-in GPS & A-GPS |
| **Video service:** | Windows Media Player, Core-Codec's CorePlayer Mobile |
| **Browser:** | Microsoft Internet Explorer Mobile |
| **Messaging:** | SMS, MMS, e-mail, Microsoft Direct Push Technology, Windows Live Messenger |
| **Sound:** | MP3, AAC, AAC+, AMR-NB, AMR-WB, WMA, WAV |
| **Video:** | H.263, H.264, MPEG4, WMV |
| **Java:** | MIDP 2.0 |
| **Processor:** | Qualcomm QSD8250 (1GHz) Snapdragon chipset |
| **OS:** | Windows Mobile 6.1 Professional |
| **Others:** | Toshiba Touch UI |

* Approximately

** Battery life and performance may vary considerably from specifications depending on product model, configuration,applications, power management settings and features utilized, as well as the natural performance variations produced by the design of individual components. Published battery life numbers are achieved on select models and configurations tested by Toshiba at the time of publication.

Specifications are correct at the time of this press release. Product design and specifications are subject to change without notice.

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# Toshiba Angio Lab Increases Availability and Patient Safety

"Thanks to our investment in new and modern technology, today we achieve both increased availability and increased patient safety", says Majid Kalani, senior physician and responsible for the angio department in the heart clinic at Danderyd hospital, which has recently been equipped with a Toshiba angio lab.

According to Kalani, the new Toshiba system optimizes workflows and allows the tasks at hand to be performed more effectively, a benefit for both patients and staff. "Before the new technology was introduced, our team was too small to handle the sheer number of patients. Length of stay increased, which drove up costs, was inconvenient for the patients, and meant more stress for the staff. This was an unacceptable situation and we had to change things. The new angio lab is an important component of this change process."

The staff of Majid Kalani have always been committed to adopting new technologies. And, Kalani underlines, it was one of his colleagues at Danderyd hospital who introduced the technology back in 2003. "Today the department carries out high-quality examinations and treatments of patients with acute and chronic diseases of the coronary vessels. The angio lab saves lives and alleviates symptoms - therefore high availability is crucial", Kalani points out.

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## Better working environment and faster recovery

"We also hope that increased availability and the state of the art equipment will lead to a better working environment for staff and patients alike. In this context lower radiation doses and better image quality are of prime importance." As availability increases, Kalani expects recovery times to decrease.

## A boost to research

Increased capacities and access to a modern angio lab triggered many research ideas in the department. "For example, we initiated a research project to examine coronary flow physiology in patients with diseases in the coronary vessels. We also want to find out why patient response to a certain drug treatment after balloon dilatation varies, and why patients with diabetes and renal failure more often suffer from cardiovascular diseases than others", says Kalani. But, with all due respect for technology, he adds, without a committed and skilled team any department stagnates. "It is great that everything functions so well, above all due to the people working in the department."

*Majid Kalani, senior physician at the heart clinic of Danderyd Hospital, Stockholm, at his workplace in the department of angiology*

**"We visited several angio labs and came to the conclusion that Toshiba's solution is smoother, faster, more modern and quieter than the others.** Our first concern is that the patients receive the best the possible care. In addition, we want the equipment to be easy to work with and easy to position. The stand with five axes, that handles the X-ray tube, is faster and more flexible to position in different angles over the patient than our former system. This is a big advantage since in the long run it means shorter examination times."

*Peter Rydberg, X-ray engineer at Danderyd hospital*




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# The Infinix-i Series


All models of the Infinix-i series possess a true multi-tasking computer that fully meets the requirements for optimum image quality, ease of use and an improved workflow. Moreover, the various types of the Inifinix-i series cover the special needs of diagnostic and interventional angiography for both radiological and cardiological purposes. An exceptional collaborative environment is created by the system's unique C-arm positioning which allows the medical and support team easy access to the patient.

The Infinix-i series combines superb image quality, unparalleled range of access for clinicians and comprehensive dose management features to ensure clinical imaging procedures that are fast, safe and precise. Dedicated and diverse system configurations support a wide range of applications.



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# Case Study
## Routine Use of Rotational Cardiac Digital Aquisition (DA)

**at Lyell McEwin Health Service and Queen Elizabeth Hospital in Adelaide, South Australia, shows benefits to patients, staff and community**

Rotational cardiac acquisition displays multiple views from one injection, improving post-stent deployment assessment in PCI. Rotational DA also reduces radiation dose and contrast media volumes to renal-impaired patients, which translates into both health and cost benefits.

Lyell McEwin Hospital is a 198-bed hospital which services the North Eastern suburbs of Adelaide and which performs in excess of 1000 cardiac cases per annum. The Toshiba InfinixTM CF-i/SP system, which was installed in June 2006, was upgraded to double axis rotational cardiac DA capabilities in March 2007. The ability to acquire rotational images has proven not only useful for routine diagnostic examinations but has extensive value for assessing post-stent deployment after performing PCIs. The ability to image a lesion, post-intervention, from multiple angles allows a better assessment of the result and minimizes the potential for complications.

| Protocol Description | |
|---|---|
| System | Infinix CF-i/SP |
| Study Protocol | Cardiac |
| Acquisition Program | Rotational DA |
| Rotational Speed | 400/s |

### Comparison of rotational cardiac DA and conventional coronary angiography

Between April 2007 and August 2008, Lyell McEwin Hospital compared the relative radiation dose (dose area product) and the volume of contrast media experienced with 55 patients using the rotational DA technique, to those recorded for another 33 patients using conventional projections. Results demonstrated reductions in dose and contrast volume by using rotational DA.

#### Reductions in dose

Results showed that using the rotational DA technique for diagnostic coronary angiography reduced dose to the patient by more than 37% compared to conventional diagnostic coronary angiography.

#### Reductions in contrast media

Results showed that using the rotational DA technique for diagnostic coronary angiography has also reduced average contrast media volume per examination compared to conventional diagnostic coronary angiography.

*Lyell McEwin cath lab staff*



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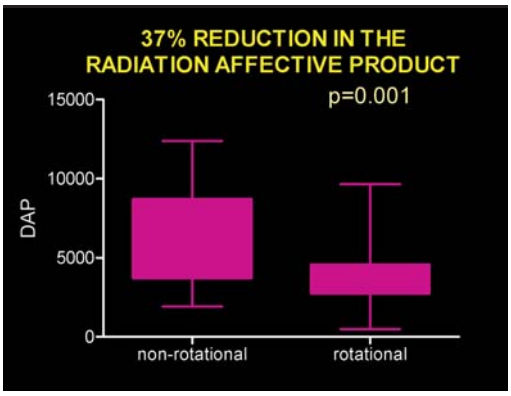
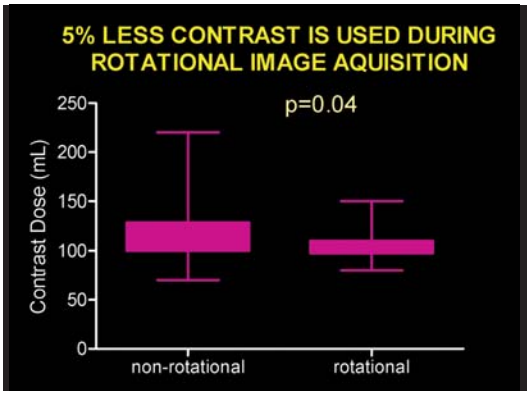



*Dose reduction using rotational DA*




*Contrast reduction using rotational DA*

*Associate Professor Christopher Zeitz*

## Renal-impaired patient benefits

Dr Zeitz performs cases at both Lyell McEwin Hospital and The Queen Elizabeth Hospital (TQEH) in Adelaide. TQEH is the sole provider of renal transplantation services to South Australia. In the cardiac cath lab at TQEH, 10% of the 2000 cases per year performed have pre-morbid impaired renal function. TQEH has also installed a Toshiba CF-i/SP multi-access C-arm on which Dr Zeitz routinely performs the rotational DA technique. Optimizing the angiographic technique from the traditional eight view coronary angiography plus a ventriculogram, to an echocardiogram for left ventricular analysis, two left coronary and one right coronary rotational injections, has reduced the average contrast media volumes from 100 mls to 130 mls, down to 50 mls per examination. According to Dr Zeitz "fewer runs with the rotational angiographic technique have led to a decrease of over 40% in average contrast media volume per examination. This is a significant benefit to our patients, many of whom already have impaired renal function. It also translates to cost saving for contrast and bed stays due to renal complications from excessive contrast administration. Advanced image processing (AIP) on the Toshiba system gives very nice images, and our staff and patients are receiving less dose. The rotational technique is very useful for assessing stent apposition from many angles with only one post-PCI injection."

*Queen Elizabeth Hospital cath lab staff*

*Lyell McEwin Hospital*
*Haydown Road*
*Elizabeth Vale*
*South Australia 5112*

*Queen Elizabeth Hospital*
*28 Woodville Rd*
*Woodville West*
*South Australia 5011*



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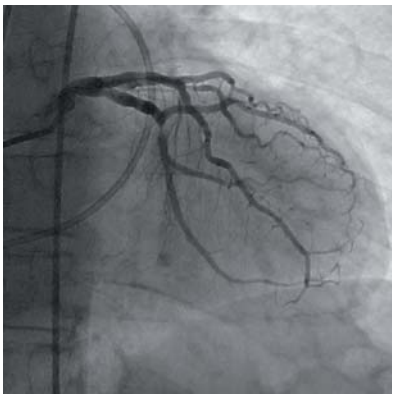
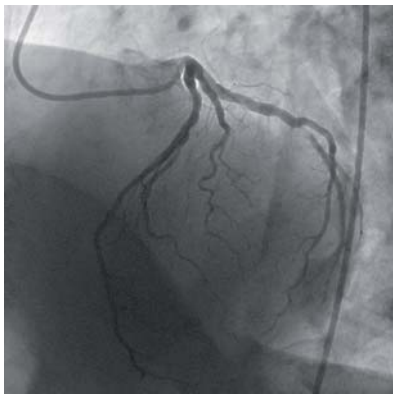
## Case Study – Clinical example of a post-PCI cardiac rotational digital angiography examination

**Patient history:** This 72-year-old male presented with an acute coronary syndrome and had recurrent symptoms. He came forward for early angiography which identified a critical stenosis in the mid-trunk of the circumflex vessel.

**Pre-PCI left coronary injection**



*Run 1: LAO 0º CAU 35º*



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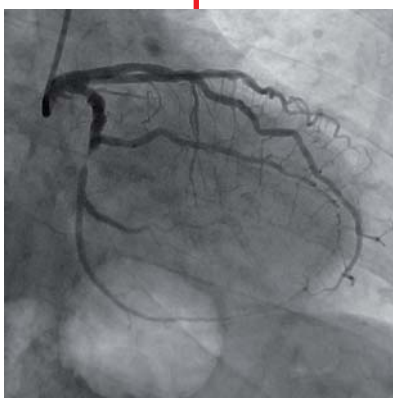

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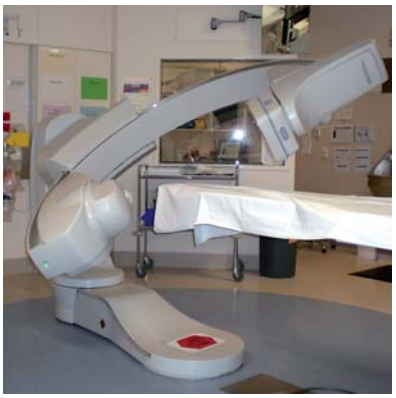
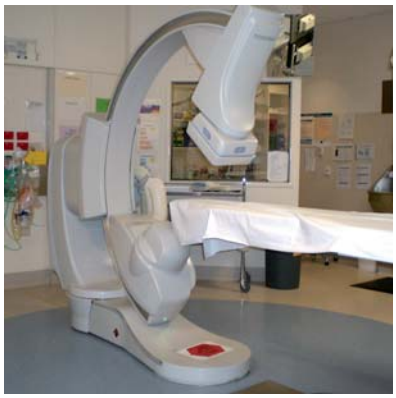
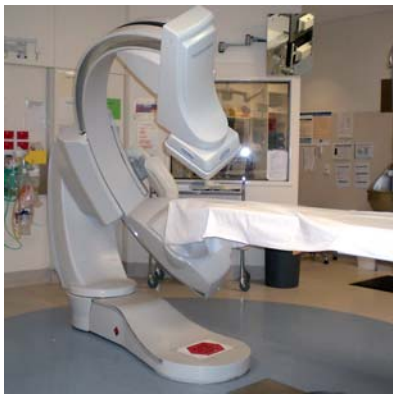


*LAO 55º CAU 35º*

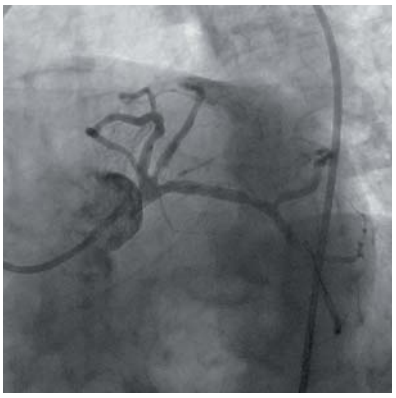


*LAO 5º CAU 35º*

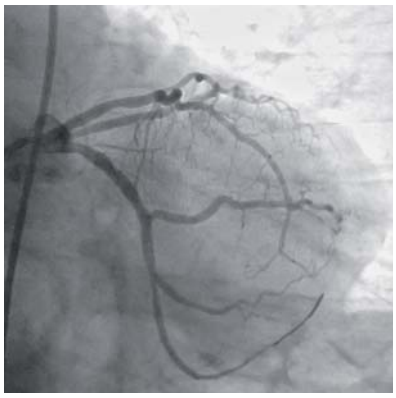


*RAO 30º CRA 35º*

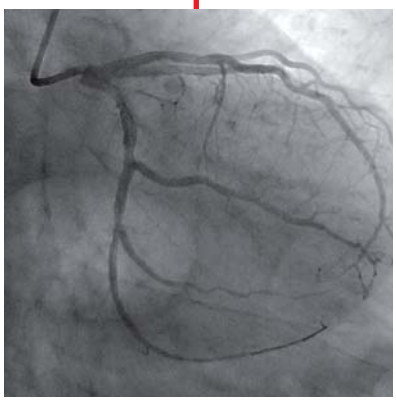
**Post-PCI left coronary injection**



*Start angle: LAO 55º CAU 35º*



*Mid-rotation angle: LAO 5º CAU 35º*



*End angle: RAO 30º CRA 35º*

**Results:** A 3 x 12 mm Liberte stent was deployed at the site of the stenosis. One injection using rotational coronary angiography allowed assessment of the stent apposition in many different angles, demonstrating an optimal result and preservation of both marginal origins



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# Prospective ECG-gated Helical 64-Detector Computed Tomography

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## A successful way to reduce patient radiation dose

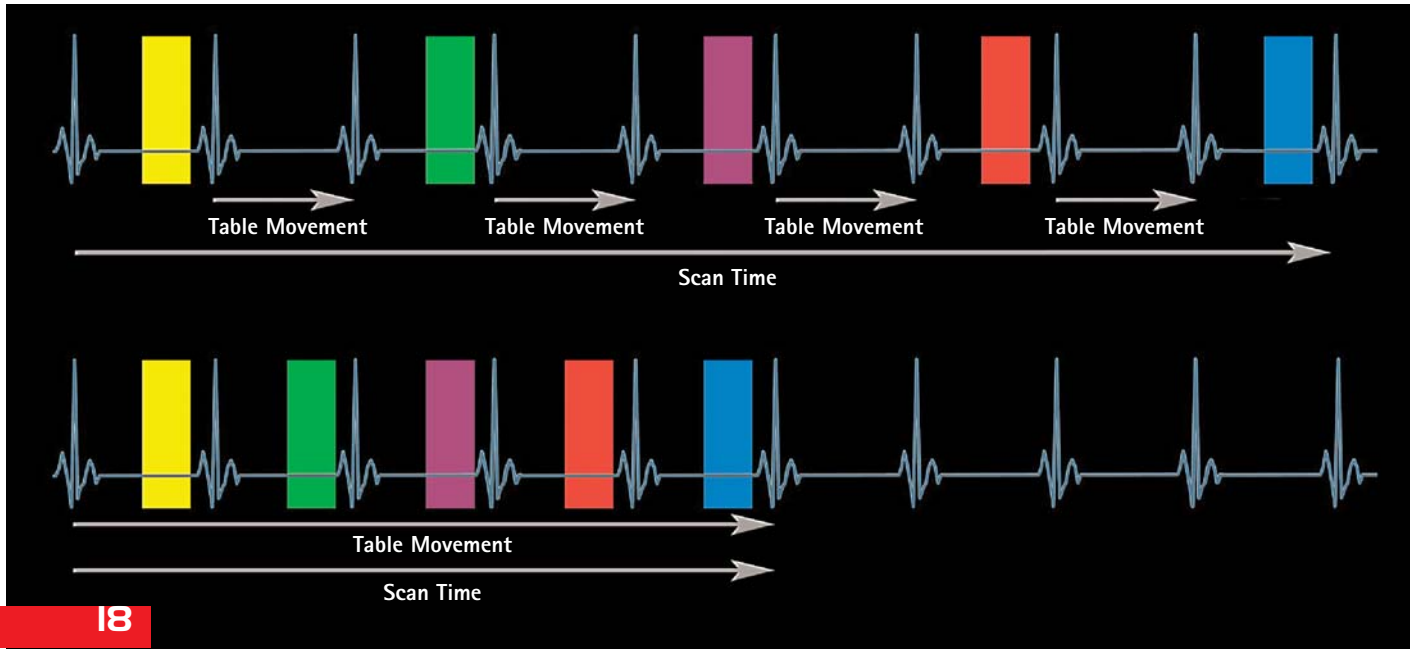
### Introduction

Major efforts are being made in order to develop non-invasive means of visualizing the coronary arteries, to avoid invasive heart catheterization. The constant development in multislice computed tomography (MSCT) has given cardiac CT a place in diagnosing cardiac disease.

We now know that cardiac CT is very efficient in diagnosing cardiac disease in patients with low to intermediate risk of coronary artery disease[1], and with an increasing number of patients undergoing cardiac CT, it is a major issue to reduce patient radiation dose. This is especially important in younger patients with a low risk of cardiac disease.

A way of reducing the radiation dose is by using SURECardio Prospective electrocardiography (ECG) gated 64-detector computed tomography (CT) developed by Toshiba. This scan method is a successful way of reducing radiation dose and still achieving the best possible image quality. SURECardio Prospective electrocardiographic gating is a technique that uses the advantages of the helical scan method with a new dose modulation technique. The helical scanning gives rapid, consistent acquisitions and collects image data at every heartbeat with no delays. This results in short scan time and short breath hold time for the patient. Also, it reduces misregistration errors and ensures a uniform contrast distribution

*Figure 1. Comparing the step and shoot method vs. SURECardio Prospective method. The upper panel shows the step and shoot method with nonspiral acquisition with no table moving during imaging, resulting in scans taken only in every other heartbeat and therefore a longer scan time. The lower panel shows the SURECardio Prospective method with a constant table moving during imaging resulting in scans taken at every heartbeat and therefore a short scan time.*



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## Case 1

**A 61-year-old female was admitted to the Department of Cardiology at Rigshospitalet, Copenhagen, Denmark, with angina pectoris.** The heart rate was 52-55 beats per minute during both the SURECardio Prospective and the retrospective scan. By using the SURECardio Prospective technique the patient radiation dose was 5.7 mSv which was a reduction of 57 % compared to the retrospective scan with normal dose modulation. There was no significant difference in image quality and the patient was easily evaluated as having normal coronary arteries with no signs of plaques or calcifications (Figure 2 a-d).

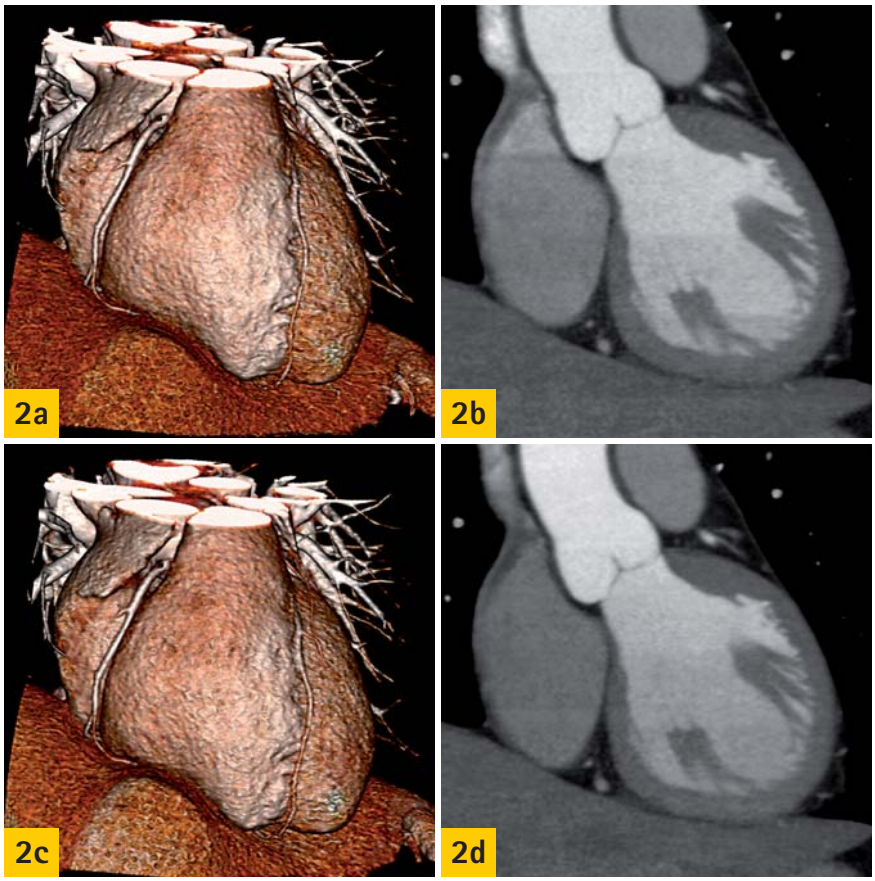


*Figure 2 a-d: Images of a normal heart.*
*Figure 2 a-b show the heart scanned with the SURECardio Prospective method.*
*Figure 2 c-d show the heart scanned with a dose modulated retrospective method.*
*There is no difference in image quality.*

throughout the vasculature. The SURECardio Prospective method reduces radiation by completely turning off radiation during the systole and in the late diastole, whereas dose-modulation during retrospective helical imaging only reduces radiation to approximately 20% of the maximum radiation value in the diastole during the systole. The area in which the SURECardio Prospective collects image data depends on the heart rate. With a heart rate below 60 beats per minute the exposure phase is 65-85%, whereas a heart rate from 65 to 70 beats per minute results in a exposure phase at 30-90%. So with patients with a heart rate from 65-70 beats per minute the image data enables functional imaging. Prospective dose figures are between 2 and 8 mSv. Depending on BMI, scan range, heart rate and scan window.

So combining the helical imaging technique and a short scan time with the SURECardio Prospective scan method results in reduced turn-on time of x-rays providing a significant radiation dose reduction and still preserve good image quality.

Another approach for reducing radiation in cardiac CT is the so-called "step and shoot" scan technique that uses forward looking prediction of R-wave timing and non-spiral acquisition with no table moving during imaging[2]. Because it is typically not possible to reposition the table fast enough to



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## Case 2

**An 81-year-old male was admitted to the Department of Cardiology at Rigshospitalet, Copenhagen, Denmark, with chest pain and dyspnoea.** The heart rate was 57-63 beats per minute during both the SURECardio Prospective and the retrospective scan. In the SURE-Cardio Prospective scan the patient radiation dose was 6.6 mSv which was a reduction of 56% compared to the retrospective scan with normal dose modulation. The image quality for the examination was good and the patient was easily diagnosed with a soft plaque on the first segment of the left descending artery (LAD) and a soft plaque on the intermediate artery (Figure 3 a-d).

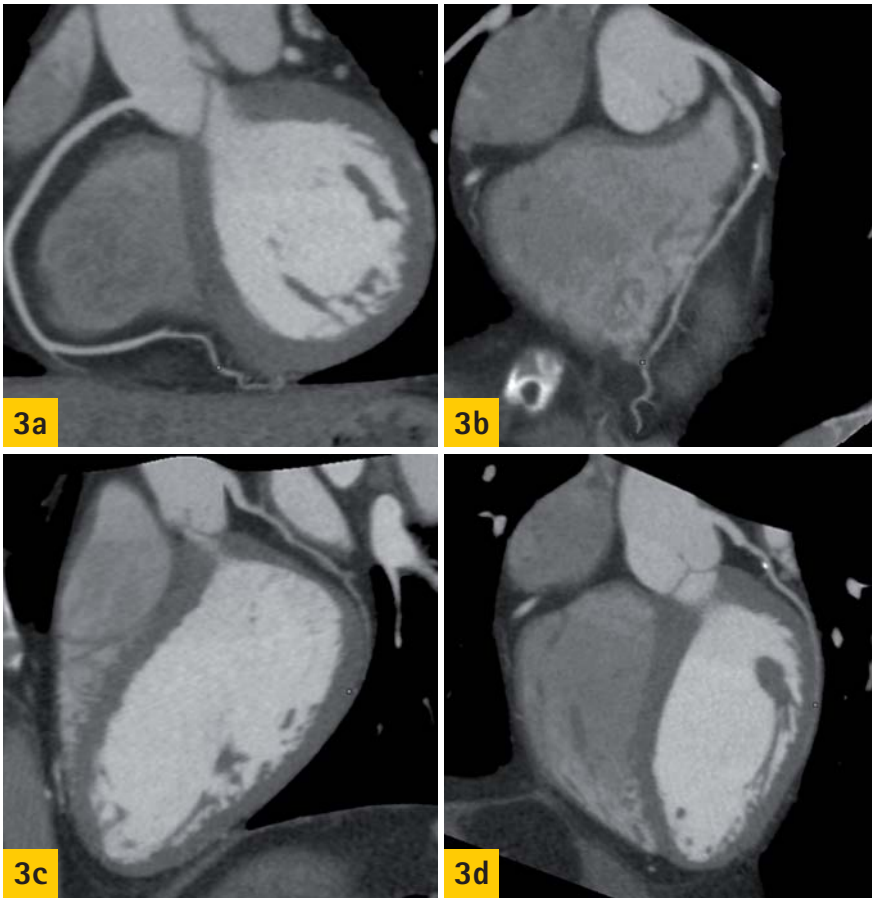


*Figure 3 a-d: Images of a heart scanned with the SURECardio Prospective method.*
*Figure 3a: A normal right coronary artery scanned with the SURECardio Prospective method.*
*Figure 3b: The left descending artery with a soft plaque in the first segment scanned with the SURECardio Prospective method.*
*Figure 3c: A normal circumflex artery scanned with the SURECardio Prospective method.*
*Figure 3d: The intermedia artery with a soft plaque scanned with the SURECardio Prospective method.*



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resume acquiring data within a single heart beat, a scan is taken in every other beat. This result in a long study time and breath hold time for the patient, and may subsequently lead to beat-to-beat variation in imaged coronary arteries causing discontinuity artefacts.

## Material and methods

In the Department of Radiology at Rigshospitalet, Copenhagen, Denmark, image acquisition is performed using a Toshiba MSCT Aquilion 64 system (Toshiba Medical Systems, Otawara, Japan) according to recommendations of the manufacturer (64 x 0,5 mm detector collimation, 100-120 kV tube voltage, 280-500 mA tube current, 350-375 ms gantry rotation depending on the heart rate).

Intravenous contrast media (Visipaque 320,) is infused with a flow rate of 5 ml/s followed by a saline chaser. The amount of contrast used is individually calculated depending on the planned scan time, which is measured during breath-hold exercises.

The prospective ECG gated method requires a heart frequency below 68 beats per minute. Therefore all patients with a heart frequency above 68 beats per minute are prepared with 50-100 mg metoprolol 60 minutes before the examination. Also 0,4 mg of sublingual nitro-glycerine spray is administrated 2-4 minutes before cardiac CT.

The patients scanned at the Department of Radiology, Rigshospitalet, Copenhagen, Denmark vary from low risk to intermediate and high-risk patients. Especially in high-risk patients a high degree of morbidity is noted and therefore many have extra systoles, elevated heart rate and a high body mass index (BMI). These factors are a challenge to the prospective scan method, while with the low and intermediate risk patients there are generally less problems, because they tend to have a low heart rate or are more easily lowered with metoprolol.

Image analysis is performed using commercially available software (Vitrea, version 3.9, Vital Images, USA). The coronary arteries are evaluated based on a 15-segment model according to the American Heart Associations recommendation[3].

## Discussion

The high amount of radiation when examining the coronary arteries with the widely used retrospective MSCT is of great concern. Therefore, there is a substantial demand for the reduction of patient radiation in a way that ensures an optimal image quality at the same time. SURECardio Prospective CT is a promising method, which by totally turning off radiation during the systole reduces radiation considerably.

In the two cases presented, the patients received both a retrospective dose modulated scan and a prospective scan as part of ongoing clinical research trial. Comparing the two methods there is a radiation dose reduction of more than 55%. At the same time we see that the image quality is almost identical and excellent. So by using the SURECardio Prospective scan method the patient radiation dose can be substantially reduced without compromising the image quality and thereby the diagnostic value of the test.

In the two cases the heart rate prior to the examination was initially steady and below 68 beats per minute, so it was not necessary to administer metoprolol. In our experience at the Department of Radiology, Rigshospitalet, Copenhagen, Denmark the main limitation of the method is the sensitivity of a stable and low heart rate of the patients. One limitation is the difficulties in lowering the heart rate. In patients with low or intermediate risk of cardiac disease this is normally not a problem, because of the low frequency of co-morbidity in this group of patients. Patients from this group are normally out clinic patients who can receive metoprolol at home before the examination if necessary, and it is therefore easy to reach a heart rate below 68 beats per minute. Many patients scanned at Department of Radiology, Rigshospitalet, Copenhagen, Denmark, however are intermediate to high-risk patients. In these patients it is sometimes difficult to lower the heart rate because of co-morbidity with elevated blood pressure, heart failure and arrhythmia. There is also a higher risk for minor irregularities in the ECG. If the heart rate rises above 68 beats per minutes or if there are irregularities during the scan the scanner software automatically switches from SURECardio Prospective mode to retrospective mode and the patients receive a full radiation dose. This feature of the software is an important advantage of the SURECardio Prospective method because it guarantees diagnostic images regardless of rising heart frequency and irregularities during the examination. The step and shoot method on the other hand has a serious limitation. According to a recent study approximately 10 % of the clinical examinations failed to give diagnostic images because of irregularities in the ECG or a heart rate rising above 60-70 beats per minute during the scan[4].

Based on the advantages and limitations described, the SURECardio Prospective method is a successful option for many patients. However, one must evaluate every patient with regard to heart rate, co-morbidity and heart rhythm when selecting between the retrospective scan with dose modulation and the SURECardio Prospective scan. The SURECardio Prospective scan method will guarantee diagnostic images and depending on the heart rate also a considerable radiation dose reduction.

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# Coronary Artery Plaque Detection and Characterization with CT in Clinical Practice

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## Abstract

During the past decade MDCT has rapidly developed from 4- to 64- and recently to 320-row detector technology. The combination of decreased width of the detector element, faster gantry rotation times and increased coverage of z-axis has resulted in continuously improved image quality. Currently, the most promising application of MDCT in cardiovascular medicine is non-invasive coronary angiography for the detection of significant coronary artery disease. Importantly, the improved image quality has also resulted in more detailed visualization of coronary artery wall. Accordingly, the state-of-the-art MDCT scanners allow assessment of coronary plaque extent and composition in addition to the severity of stenosis. Moreover, imaging of the coronary arteries has currently become possible with substantially lower radiation exposure and reduced amount of intravenous contrast. The purpose of this review is to provide an overview of current applications of MDCT in imaging of different patterns of coronary atherosclerosis. In addition, potential benefits for imaging of coronary artery plaques with recently introduced Toshiba CT scanners are discussed.

## Introduction

During the past decade, extensive efforts have been made in the development of modalities enabling non-invasive anatomical imaging of the coronary arteries. Having been introduced in the late 1990s, multi-detector computed tomography (MDCT) is the most recent modality. Due to relatively simple and extremely fast image acquisition the technique is currently considered to be the most robust modality for non-invasive coronary artery imaging.

In less than a decade the technology developed from the MDCT scanners containing four detector rows to the introduction of the scanners with 64 detector rows, allowing increasingly wider coverage of the z-axis. The improvements in craniocaudal volume coverage were paralleled by decreased gantry rotation time, and smaller detector elements (Table 1). Accordingly, improved temporal and spatial resolution resulted in improved image quality[1]. Recent introduction of wide detector 320-row dynamic volume CT enables non-helical imaging of the entire heart in a single gantry rotation, hereby allowing cardiac imaging in one heart beat as well as minimizing motion artifacts due to variations in the length of the R-R intervals and breathing during image acquisition. In addition, low-dose scanning became possible due to the possibility to scan prospectively in a narrow window of the R-R interval in a single heart beat[2].

The purpose of this review is to provide an overview of currently available data on imaging of coronary atherosclerosis with current state-of-the-art 64-row MDCT. In addition, the emphasis is given to the discussion of possible benefits of imaging of coronary plaques with wide detector 320-row volume CT.

### Imaging of coronary plaque extent with MDCT

MDCT coronary angiography allows assessment of coronary artery plaque burden since both non-obstructive and obstructive (luminal narrowing ≥50%) coronary plaques can be detected. As the degree of luminal narrowing of individual lesions and the number of obstructive coronary stenoses provide important diagnostic and prognostic information[3], this information was most extensively explored after the introduction of MDCT. Whereas the diagnostic accuracy to detect significant coronary lesions with the early 4-slice CT scanners was limited, the introduction of 16-slice CT with improved spatial resolution provided substantial increase of the diagnostic accuracy to detect significant coronary stenoses[4]. With the introduction of 64-row CT it became possible to visualize the entire coronary artery tree (including distal parts of the coronary arteries). Indeed, the weighted mean sensitivity for the detection of coronary artery stenoses with the state-of-the-art 64-row CT was as high as 93%, whereas the specificity was 96%, while no segments had to be excluded from the analysis[1]. The initial data on the diagnostic accuracy of non-invasive coronary angiography with wide detector volume CT, which allow data acquisition during a single heart beat, are promising. Indeed, on segmental level reported overall diagnostic accuracy was 94%[5]. Accordingly, the technique provides important information in diagnostic and therapeutic decision making. Neverthe-



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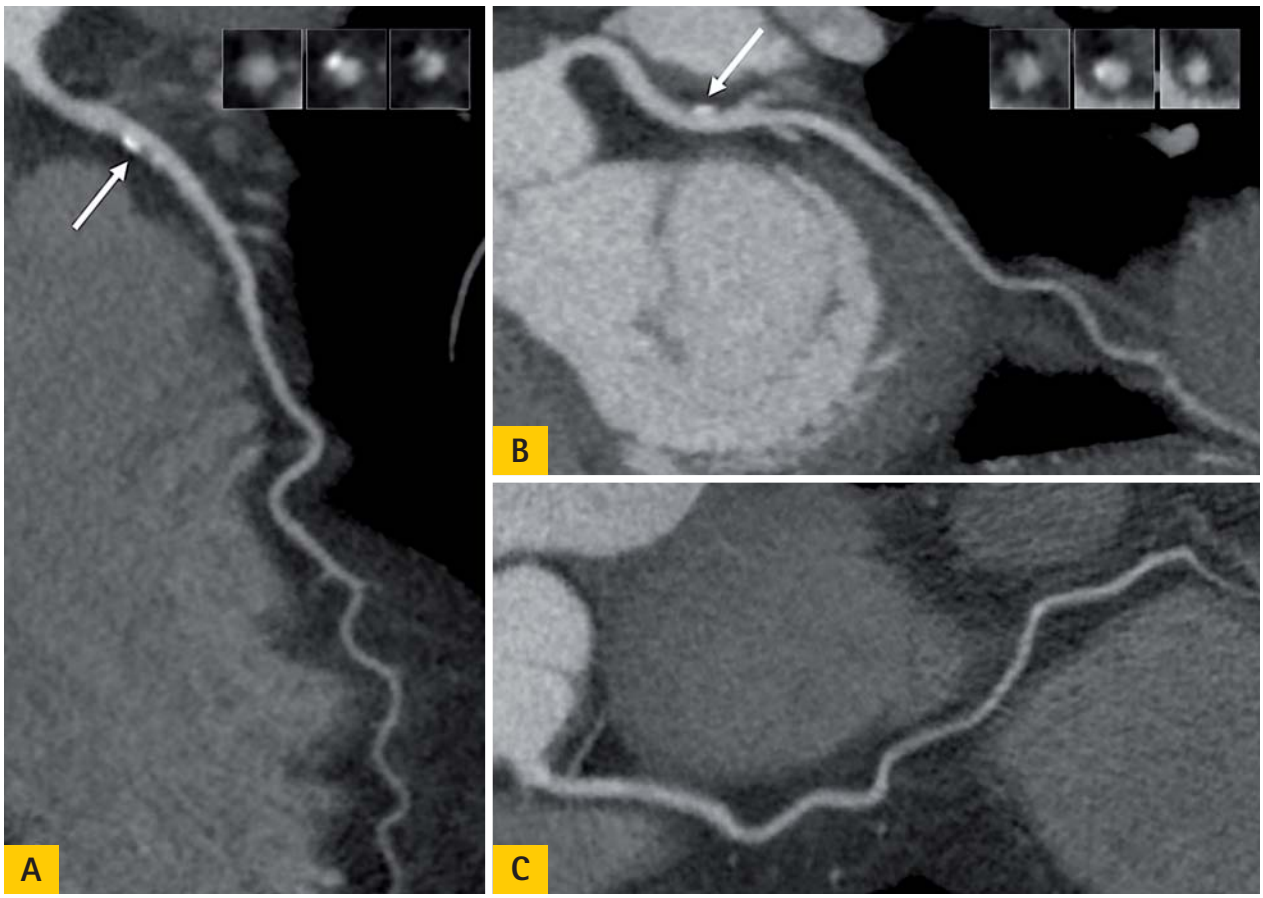


*Fig. 1: 320-row dynamic volume CT coronary angiography of a 57-year-old male presenting with atypical angina pectoris, hypertension, history of smoking, and a positive family history of coronary artery disease. CT showed non-obstructive mixed plaques (a combination of non-calcified and calcified tissues within the same plaque) in the proximal left anterior descending coronary artery (A, arrow), and the proximal left circumflex coronary artery (B, arrow). Minor wall irregularities were observed in the right coronary artery (C).*

less, it is important to realize that the assessment of stenosis severity on MDCT is at present visual (qualitative), whereas no validated stenosis quantification algorithms are currently available. Indeed, only a moderate correlation between the quantitative 64-row CT coronary angiography and quantitative invasive coronary angiography was previously observed (r = 0.54), whereas the degree of luminal narrowing on MDCT tended to be overestimated[6]. As the ability to quantify coronary artery stenoses would increase the reproducibility of the technique, the lack of quantification algorithms is currently considered to be a limitation of MDCT.

Together with the detection of obstructive coronary artery lesions, MDCT coronary angiography also enables imaging of coronary artery wall. Accordingly, information on the spatial distribution and volume of coronary artery plaques may be obtained. Indeed, the distribution of both non-obstructive and obstructive coronary artery plaques may be visually assessed and robustly quantified by assessing the number of coronary artery segments containing plaques, as previously suggested[7]. Using the above visual quantification method, which provides a general estimation of the distribution of coronary plaques, differences in coronary plaque extent were observed on MDCT in patients with regard to their clinical presentation. Indeed, in a previous study exploring coronary plaque distribution in patients with type 2 diabetes, diabetic patients tended to contain more non-obstructive and obstructive plaques[8]. Similarly, patients presenting with suspected acute coronary syndromes contained more coronary plaques as compared with patients presenting with stable coronary artery disease (CAD)[9]. Possibly, the above information obtained by means of a simple visual quantification method may be clinically relevant in the diagnostic and prognostic work-up of patients presenting with suspected CAD[7,10]. Nevertheless, the ability to quantify coronary artery plaque with the application of validated algorithms would be even more beneficial with regard to reproducibility and possibly enabling monitoring of the treatment effects. Otsuka et al have recently investigated the accuracy of coronary plaque quantification on MDCT as compared with intravascular ultrasound (IVUS)[11]. Although a good correlation was observed between MDCT and quantitative IVUS (r = 0.96), plaque volume was overestimated with MDCT with a mean of 7 ± 33 $mm^3$. In particular, non-calcified plaque volume was generally underestimated on MDCT, whereas the calcium-containing plaque volume was slightly overestimated on MDCT as compared with IVUS. The reported reproducibility of measurements was good. Accordingly, although the available data on quantification of coronary plaque with the state-of-the-art 64-row CT are promising, further improvements in MDCT technol-



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| Parameters | 4-slice | 16-slice | 64-row | 320-row |
|---|---|---|---|---|
| Gantry rotation time (ms) | 500 | 400 | 350 | 350 |
| Temporal resolution (ms) | 83-250 | 67-200 | 58-175 | 58-175 |
| Slice thickness (z-axis (mm)) | 2 | 1 | 0.5 | 0.5 |
| In-plane resolution (x-y axis ($mm^2$)) | 0.4 | 0.4 | 0.4 | 0.4 |
| z-axis coverage (mm) | 8 | 16 | 32 | 160 |
| Average breath-hold time (s) | 30-40 | 20 | 10 | 1 |

*Table 1: Technical parameters of Toshiba CT scanners*

ogy are necessary. The introduction of wide detector row dynamic volume CT with non-helical image acquisition within a single heart beat provides more uniform contrast distribution and minimizes the motion artifacts due to differences in the R-R intervals occurring when data are acquired during several heart beats[2]. Accordingly, these new developments may provide more accurate plaque imaging resulting in more precise plaque quantification as compared with the previous scanner generations. Nevertheless, data on plaque imaging with this new technology are awaited in the near future.

## Imaging of coronary plaque composition with MDCT

In addition to the ability to detect both non-obstructive and obstructive coronary artery lesions, an important feature of MDCT coronary angiography is the ability to differentiate between non-calcified and calcified coronary plaque. Indeed, since a large number of myocardial infarctions and sudden deaths occur as a result of rupture of non-obstructive coronary artery lesions, it has been hypothesized that plaque composition plays an important role in the development of cardiovascular events[12]. Accordingly, the possibility to non-invasively assess coronary artery wall has become subject of extensive investigation. Three different types of plaques can be visually assessed on MDCT. Non-calcified plaque contains tissue with lower density as compared with the contrast enhanced lumen and has no visible calcification. Mixed plaque contains both non-calcified tissue and bright calcification within the same plaque. Calcified plaque is defined as a structure with density which is higher than the contrast enhanced coronary artery lumen. Previous studies have been conducted to provide comparisons between non-invasive assessment of coronary plaque composition on MDCT and invasive IVUS[13-15]. Indeed, a good accuracy to detect non-calcified and calcified tissue was observed with MDCT. In a previous study, non-calcified plaque was detected on MDCT in 83% sections containing non-calcified tissue on invasive IVUS, whereas MDCT correctly identified 94% of sections containing mixed plaque, and 95% sections containing calcified plaque[13]. Similarly, comparisons of the three plaque types on MDCT with invasive virtual histology IVUS (VH IVUS) revealed a good correlation between the two techniques[14]. Indeed, non-calcified plaques on MDCT contained more fibrotic and fibro-fatty tissues on VH IVUS as compared with calcified plaques. Similarly, calcified and mixed plaques on MDCT contained significantly more calcified tissue on VH IVUS as compared with non-calcified plaques. Moreover, the mean density expressed in Hounsfield units (HU) was significantly lower in non-calcified plaques as compared with fibrous and calcified plaques[15]. Accordingly, since MDCT allows detection of three plaque types with a relatively high accuracy, previous studies have been performed to compare coronary plaque composition among patients with different clinical presentations. Indeed, more non-calcified tissue containing plaques were observed on MDCT in patients presenting with acute coronary syndromes as compared with patients presenting with stable CAD[16,17]. Similarly, patients with type 2 diabetes were observed to have relatively more non-calcified and completely calcified plaques as compared with patients without diabetes[8,18]. Potentially, the information on plaque composition could be useful for improved risk stratification. Indeed, a recent study showed that the presence of non-calcified plaque resulted in enhanced risk stratification incremental to the combination of clinical variables, data on myocardial perfusion, and significant stenosis on MDCT[19]. Nevertheless, prognostic data of these observations are currently scarce, and further research is necessary to understand the potential value of MDCT plaque imaging in risk stratification. The clinical example of non-invasive CT angiography is provided in Figure 1.

Moreover, it is important to understand that due to the inferior spatial resolution, MDCT provides a more general estimation of coronary plaque composition as compared with the information obtained with invasive IVUS. Indeed, in a study comparing plaque composition between MDCT and VH IVUS, non-calcified plaques on MDCT contained a small amount of calcified tissue which was not observed on MDCT. Moreover, completely calcified plaques on MDCT contained a substantial amount of non-calcified tissues on VH IVUS[14]. Similarly, the differentiation between lipid-rich and fibrotic tissues on MDCT may be difficult[20]. This differentiation may further be complicated due to the nature of MDCT imaging. Indeed, external factors such as the opacification of coronary artery lumen with contrast media, the body mass index and cardiac output may significantly influence the measurements of coronary plaque density thereby further increasing overlap between the densities obtained in lipid-rich and fibrotic plaques[21]. Nevertheless, further developments of MDCT scanners may reduce the present limitations significantly.



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### Coronary plaque imaging with wide detector dynamic volume CT

The major advantage of the recently introduced wide detector volume CT as compared to the previous scanner generations is the possibility to image the entire heart within a single non-helical gantry rotation. In addition, the possibility to scan prospectively in a narrow window of the R-R interval in a single heart beat enables low dose scanning with a radiation exposure of as low as 1.7 mSv[22], whereas the image acquisition time is less than one second. Moreover, along with reduced motion artifacts due to scanning in a single heart beat, non-helical image acquisition during a single gantry rotation allows a more even distribution of intracoronary contrast within coronary artery tree. Indeed, in a recent study the mean difference of contrast opacification at the coronary artery ostium and distally in the coronary arteries was 37.7 HU, whereas the contrast opacification gradient was relatively consistent along the different coronary arteries[2]. Accordingly, a more reliable evaluation of plaque extent and composition along the entire coronary tree may be expected with the wide detector scanner. In addition, due to a short acquisition time, the amount of intravenous contrast is significantly reduced to 50-60 ml. Finally and importantly, imaging the entire heart during a single non-helical gantry rotation enables performing of coronary angiography and assessment of myocardial perfusion at rest, followed by acquisition during stress in a single session. Accordingly, both anatomical and functional information on coronary artery lesions can potentially be obtained with an average radiation dose of 13.5 mSv[23]. Since a discrepancy between anatomical and functional information of coronary artery lesions has been previously demonstrated, this may become an important advantage. Indeed, about half of obstructive lesions on MDCT resulted in the absence of ischemia on myocardial perfusion imaging[24]. Accordingly, the ability to obtain anatomical and functional information of coronary artery lesions in a single session may facilitate rapid therapeutic decision making.

## Conclusions

During the past several years MDCT has developed as a non-invasive imaging modality providing accurate diagnosis of severe coronary artery lesions. Current state-of-the-art 64-row CT scanners enable visual assessment of the coronary plaque burden as well as of the extent of non-calcified and calcified plaques. Potentially, the information on coronary atherosclerosis on MDCT may provide clinically relevant information for risk stratification. It is anticipated that the recent introduction of MDCT scanners with wide detectors will result in improved quantification of coronary plaque volume and a more precise assessment of plaque composition. In addition, evaluation of coronary atherosclerosis and myocardial perfusion in a single session may become feasible. Nevertheless, as the technique is relatively new, more studies are required before imaging of coronary atherosclerosis may be widely applied in clinical practice.

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# CT-guided Brachytherapy – planning and treatment of gynaecological cancers

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## Introduction

In 2006, a large-bore CT scanner, Aquilion LB, was installed at the Department of Radiology at Kuopio University Hospital (Kuopio, Finland). Its role was to provide a CT simulator for external radiotherapy and to serve as an imaging device for brachytherapy (BT) treatments (Fig. 1). A CT scanner with such a large aperture allows the use of various - even large - fixation devices for patients undergoing external radiotherapy. It also enables brachytherapy patients to be treated on the CT couch in different positions, allowing better access to the treatment site. In the course of three years we have treated more than 150, mostly gynaecological BT patients under CT guidance based on 3D image geometry.

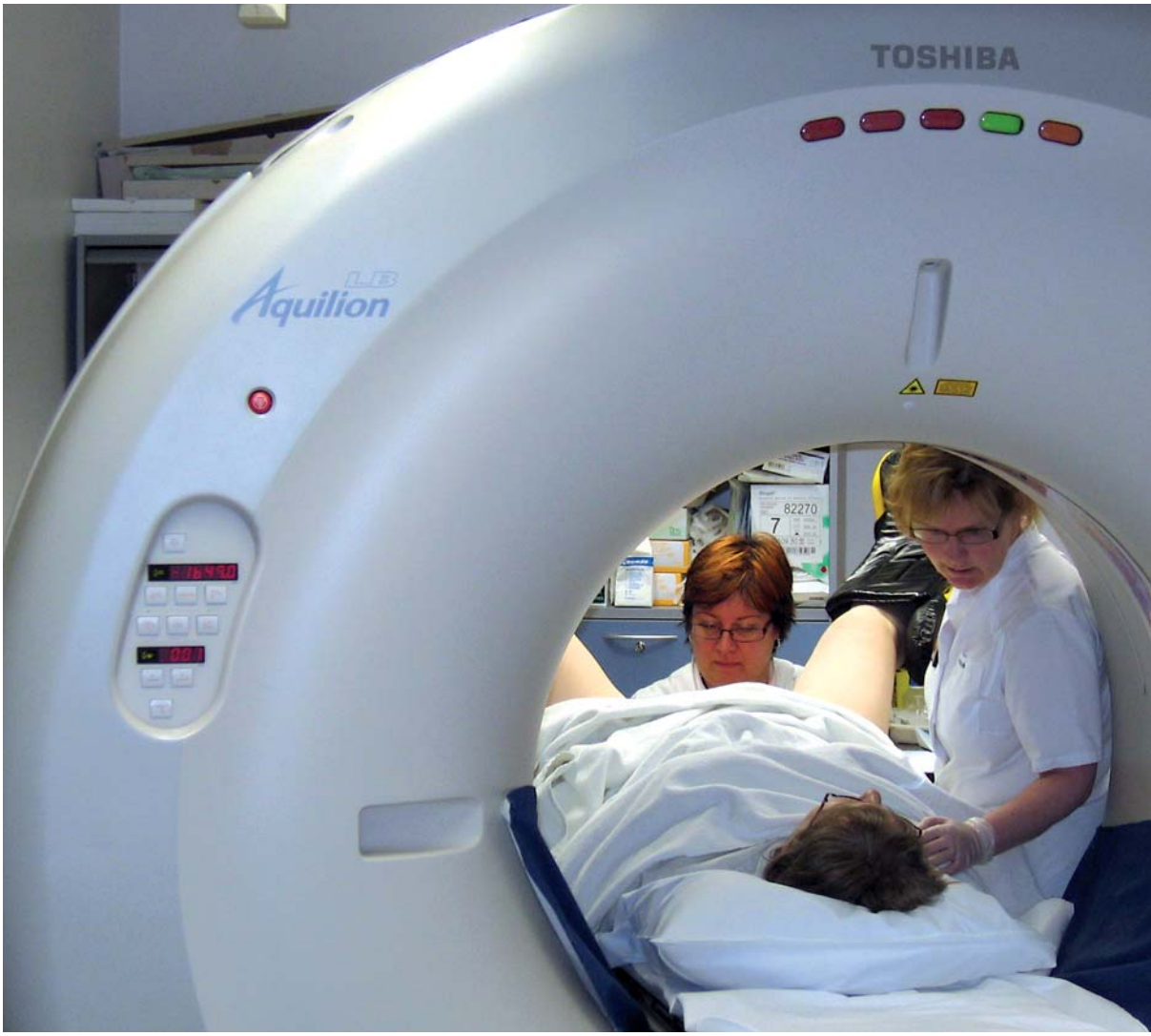


*Fig. 1: 16 -slice large-bore Toshiba Aquilion installed at the Radiotherapy Department of Kuopio University Hospital – a typical brachytherapy day.*



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*Fig. 2: Foot holder device fixed to CT couch (radiotherapy top). Only one foot support is fixed.*

## Short introduction to brachytherapy

Brachytherapy is a form of radiotherapy in which the radioactive source (isotope) is introduced as close to the tumor as possible and held there for a defined period of time. In modern so-called high dose rate (HDR) brachytherapy the radiation sources are highly active in order to minimize treatment time and achieve radiobiological effectiveness comparable to that of external radiotherapy. The treatment is performed with an afterloader device. While the afterloader is not in use, the active source is stored inside a radiation shield. The source, typically Iridium-192 isotope capsule, is attached to the tip of a long wire. Before treatment, one or several applicators are inserted into the patient either intracavitary or interstitially, so that the applicator is located as close as possible to the target area. The applicators are then connected to the afterloader via transfer tubes, so that the source wire can travel from the afterloader through the tubes, inside the applicator and patient. This procedure is performed remotely thus hospital staff is not exposed to radiation. Actual treatment times once the source is inside the patient vary between 2 and 20 minutes depending on the treatment plan and activity of the used source. The main patient groups for HDR brachytherapy are gynaecological patients (with cervix, uterus and vaginal carcinomas), prostate, breast, bronchial tumors, head & neck tumors, etc[1].

## MRI vs. CT

Today, gynaecological BT, especially the treatment of cervical cancer, involves 3D imaging of the treatment site[2]. Thus, European dose standards are based on 3D anatomy information. The gold standard for 3D imaging is MRI, a modality which due to time constraints in many hospitals, is rarely available. For BT treatment, however, CT imaging with contrast enhancement is an alternative .

The advantages of a large-bore CT scanner instead of MRI are good visibility of treatment applicators and organs at risk and the possibility to scan the patient frequently during insertion in order to achieve optimum applicator position. If the CT scanner is installed in the HDR treatment room the patient can be treated in the same position in which the applicators were inserted which means more accurate treatment and shorter treatment times. Moreover, since no patient transport from MRI to the treatment room is required and imaging times are much shorter with CT than with MRI total treatment times are reduced.

## Our method and patients

In Kuopio University Hospital our main BT patient group is patients with gynaecological tumors, mainly cancers originating from uterus or cervix. Serving a region with 860 000 inhabitants, our department has approximately one to two new gynaecological BT patients per week. The majority of these are uterine cancer patients who underwent surgery. Depending on the staging of the disease, some of these patients may need prophylactic irradiation of the distal part of the vaginal wall to prevent possible tumor spread. At our hospital we offer BT radiotherapy over one week, with treatment sessions taking place every other day, so the patients can remain at home between sessions.

During the last two years, we have treated approximately 130 gynaecological patients with CT guidance. We installed a CT scanner in the shielded treatment room which allows us to insert and fasten the applicator and immediately treat the patient.



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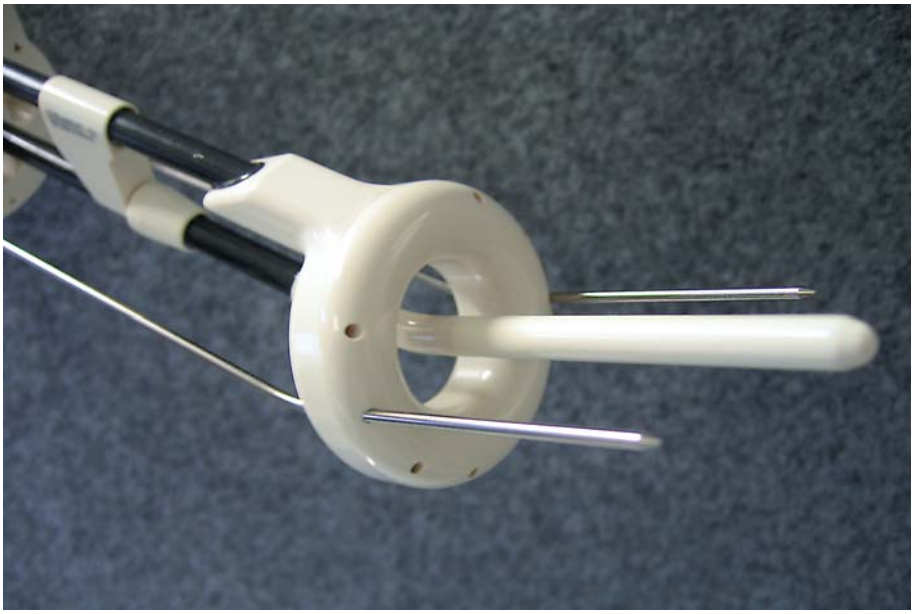

*Fig. 3: Vienna applicator with optional titanium needles inserted for interstitial treatments. Mainly used for the treatment of cervical cancer.*

Thus we avoid any unintentional movement of the applicator which might result in undesired dose distribution to the tumor and to critical organs. In order to treat patients in lithotomic position a special foot holder was developed with Toshiba and Civco Corporations which allows the physician to position the patient's legs easily during the application procedure (Fig. 2).

## The procedure

Each BT procedure is meticulously planned. The gynaecologist has examined the patient and if the procedure demands a MRI scan, it is performed beforehand. Applicator type and size are selected depending on the treatment site and patient anatomy. If parts of the tumor cannot be reached with a standard intracavitary applicator, a custom applicator can be made and/or invasive interstitial needles can be inserted via holes in the applicator which takes them to the target area. This new type of applicator, the Vienna ring applicator by Nucletron, named after the development place/group (Fig. 3)[3,4], is MR/CT-compatible without any metal parts and minimizes image artefacts. After the preparation, the patient lies on the CT scanner couch in lithotomic position, feet towards and through the gantry, and a gynaecologist starts the application behind the gantry (Fig. 4). This position allows the gynaecologist free access to the patient. If anesthesia is required, anesthesia staff work from the other side of the gantry thus giving the team members behind the gantry plenty of space. This kind of access to the patient requires a particular gantry design: the opening should be wide and not tunnel-like to allow lithotomic positioning and the gantry itself should be narrow enough so that the anesthesia group has good access to the patient's face.

Once applicator and optional needles are in place, the patient is imaged in the same position. After scanning, the radiotherapy plan is established on the basis of the acquired images. To get an accurate 3D image and to enable reconstruction of any slice orientation, slices are taken helically and reconstructed at 1 mm width and 1 mm intervals. Thus, the resulting 3D image is isotropic. Images are then imported to a planning software. The gynaecologist identifies the target as well as the organs-at-risk-area and defines the radiotherapy doses in the planning software. Based on the 3D anatomical information, the physician can make sure that the target tissue covers all cancerous areas and that the doses to the adjacent healthy organs - rectum, bladder and sigmoid - are limited. Before imaging, an iodine contrast agent is used to visualize bladder and rectum better.

The radiotherapy plan established by a physicist is based on recommendations[1] and the treatment is started as soon as the plan is available. The whole procedure takes about one to three hours, depending heavily upon the treatment type. If interstitial needles are required it takes longer since both application and planning are more complex.

## Results and discussion

CT imaging can contribute to the brachytherapy treatment being more compliant, protecting healthy organs from unnecessary radiation and thus reducing the side effects of BT. This increased accuracy allows the treatment dose to be increased while morbidity decreases. CT-based imaging also enables ad-



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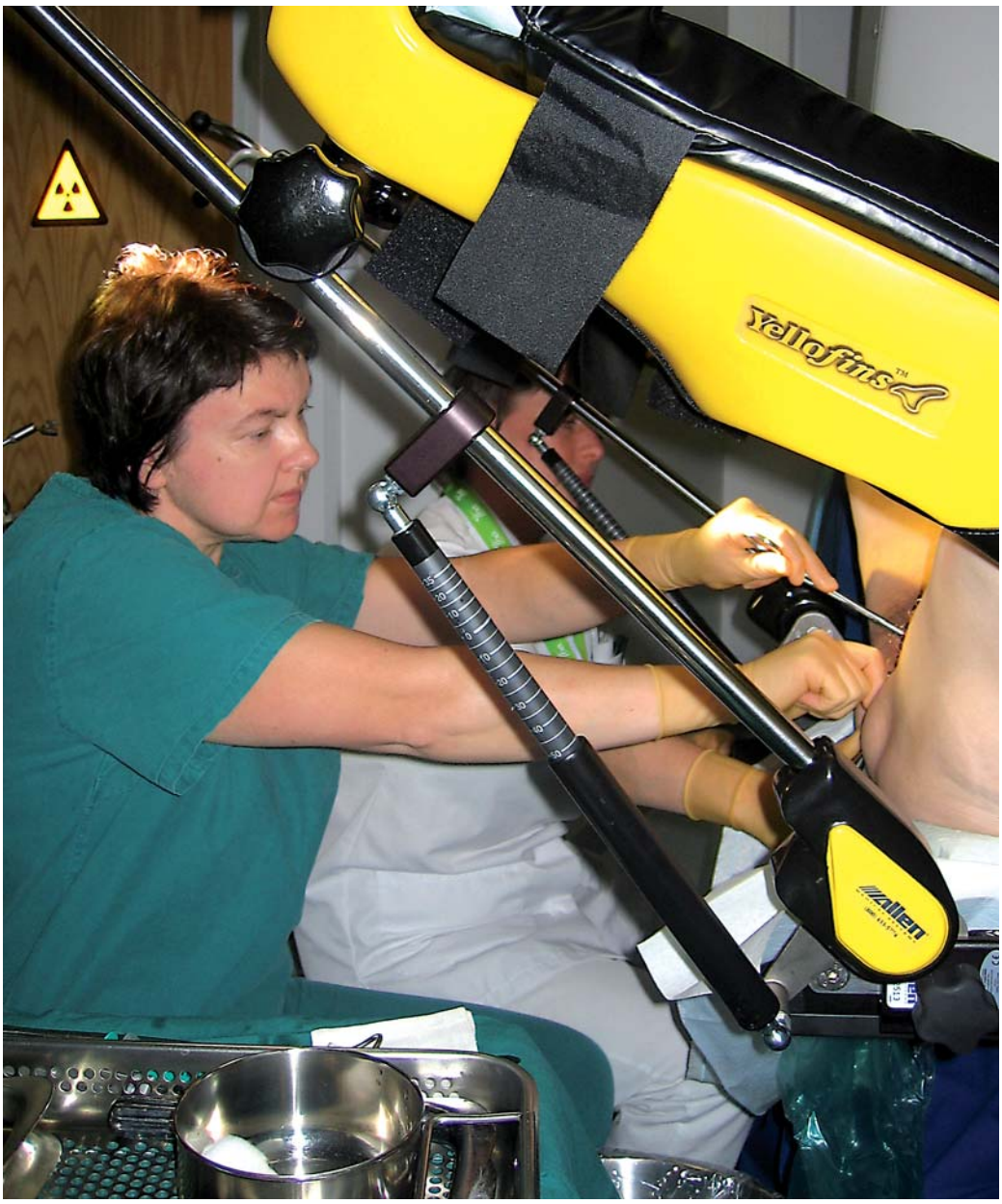


*Fig. 4: The procedure – gynaecologist inserting the treatment applicators behind the gantry*

justing the dose in rather simple BT treatment types, for example in vaginal cuff treatments, which are traditionally planned using a pre-defined standard for all patients. In a standard plan, the prescribed dose (isodose curve) is fixed at 5 mm distance from the applicator surface. With CT imaging we can now see the patient-specific thickness of the vaginal wall and modify the plan accordingly. Thus, we can adjust the dose so that it covers the entire vaginal wall including scar tissue at the bottom of the vagina. Moreover, bladder and bowel can be taken into account in planning.

Using both MRI and CT provides even more detailed information of the anatomy. MRI helps the physician to distinguish cancerous areas from healthy anatomy, which, however, is difficult, especially for cervical cancer. In Kuopio University Hospital, we have treated patients with MRI-assisted brachytherapy including pre-treatment CT imaging in order to identify any possible applicator/anatomy movement before the treatment.

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# MDCT Scanning: – automated cardiac phase selection using phaseXact

**phaseXact detects the optimal diagnostic phase for CT coronary artery evaluation and improves the workflow**

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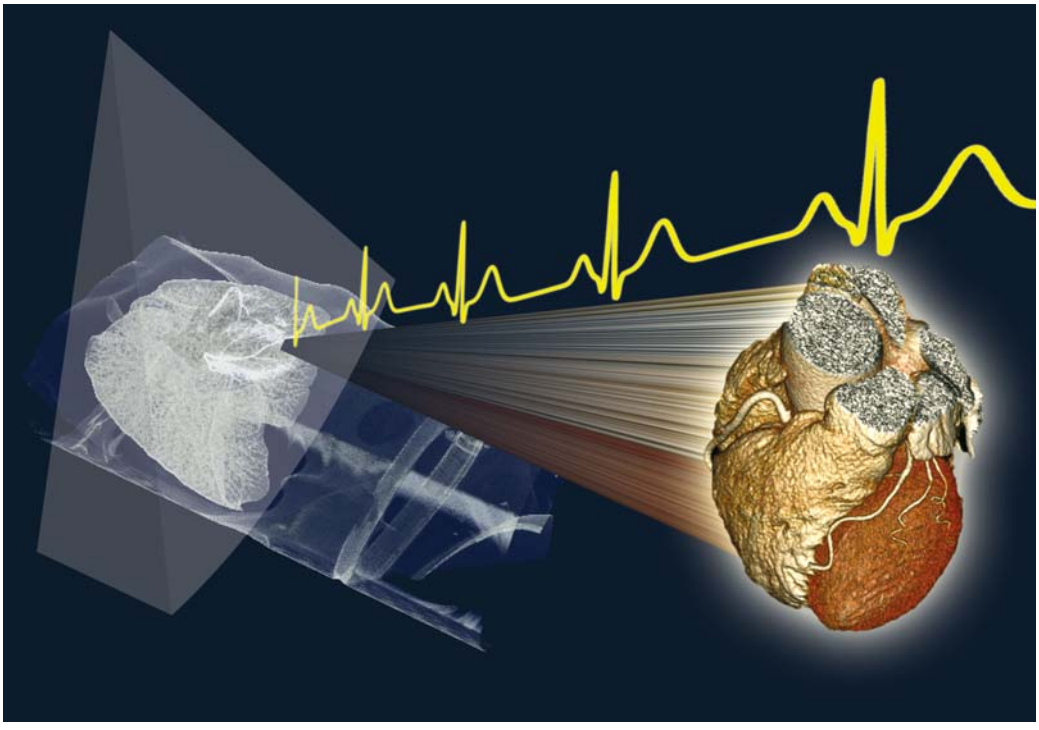
## Introduction

The amount of cardiac multidetector computed tomography (MDCT) examinations is rapidly increasing worldwide, due primarily to new MDCT technology, such as wider detectors and short tube rotation times. A recently published international multicenter study has shown that cardiac MDCT scanning on a 64-MDCT scanner is very accurate in detecting coronary diseases[2]. Further improvement has been accomplished on the new Aquilion ONE (Toshiba Medical Systems) which is the first scanner with a beam width of 160 mm in combination with a tube rotation time of 0.35 s. The Aquilion ONE gives a new impulse to cardiac MDCT by scanning the whole heart in just one rotation with superior image quality (Fig. 1)[3,4].

The great advantage of coronary MDCT above conventional cardiac catheterization is that cardiac MDCT is a non-invasive technique. This minimizes the patient discomfort and avoids the risks inherent in catheterization.

During MDCT scanning, raw image and ECG data are recorded and both data sets are stored. Image reconstruction starts with selecting the adequate cardiac phase; that is the phase with the least motion. Selection of the optimal rest phase is essential to avoid motion artifacts and obtain images that are suitable for clinical evaluation.

*Fig. 1: With the new Aquilion ONE the whole heart can be scanned in just one rotation by the large beam width, with simultaneously recording of the ECG. In just one rotation excellent image quality can be achieved.*



*Note: Parts of this study were published in more detail in the American Journal of Roentgenology[1]*



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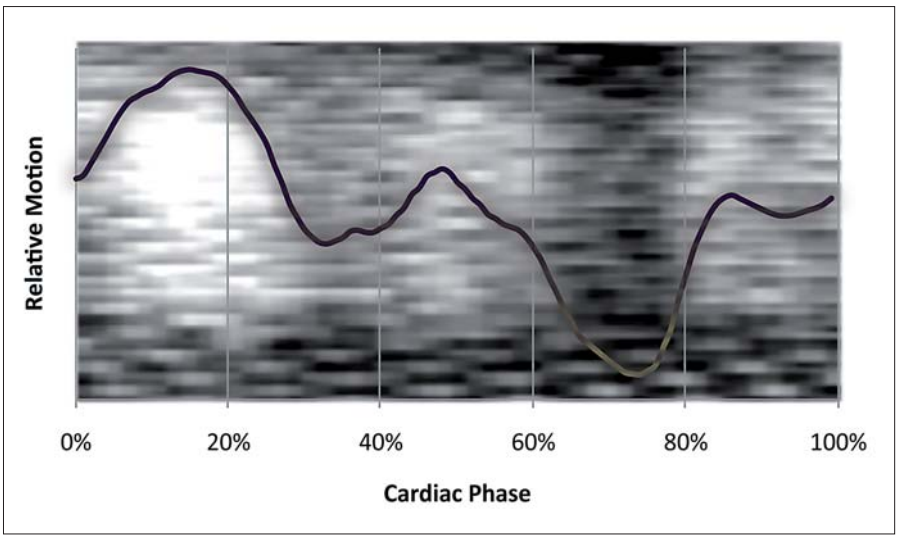



*Fig. 2: In the background the image shows the motion map which is used for calculating the motion graph.*

Optimal phase selection can be performed with three methods:

1. using a single predefined phase,
2. selecting the best phase with the least motion throughout the cardiac cycle manually by visual inspection,
3. using an algorithm (phaseXact, Toshiba Medical Systems, Otawara, Japan) which detects the optimal phase automatically[5,6].

The first method is well suited for reconstruction of images of the coronary arteries at relatively low heart rates. At higher heart rates, reconstructions may result in unacceptable motion artifacts.

Selecting the best phase manually by visual inspection demands more operator time but may be expected to result in images with less motion artifacts and thus improved image quality compared with predefined phase selection.

The algorithm that automatically detects the optimal rest phase with the least motion may be advantageous in clinical practice, although clinical studies and comparisons with other reconstruction methods have not been performed.

The aim of the study was to assess the three methods to select the optimal phase for image reconstruction and each method's effect on the image quality of 64-MDCT coronary angiography studies.

## Materials and methods

### Patients

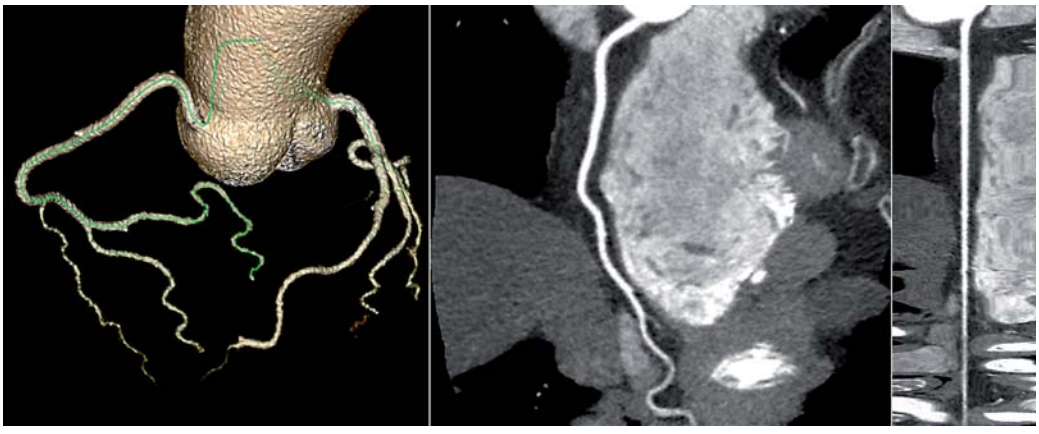
CT coronary angiography studies of 40 patients (23 men, 17 women; mean age, 56 years; age range, 30–78 years) were selected. The group was composed of 20 consecutive patients with heart rates ≤ 65 beats per minute (bpm) (mean heart rate, 55 bpm; heart rate range, 48–64 bpm) and 20 consecutive patients with heart rates > 65 bpm (mean heart rate, 76 bpm; heart rate range, 66–105 bpm). The heart rate condition was applied to the mean heart rate during image acquisition; heart rate variability was not taken into account. All patients had undergone CT coronary angiography for clinical indications to evaluate the coronary arteries.

### Scan and reconstruction parameters

Contrast-enhanced CT coronary angiography was performed using an MDCT scanner (Aquilion 64, Toshiba Medical Systems).

Data acquisition was performed using the following parameters: slice collimation of 64 x 0.5 mm, tube voltage of 120–135 kV (dependent on patient weight), tube current of 300–400 mA (dependent on patient weight), and scanning field of view of 240 or 320 mm. The optimal pitch factor and rotation time were automatically determined by cardiac scanning software ([SURE]Cardio, Toshiba Medical Systems) to obtain optimal temporal resolution at every heart rate.

*Fig. 3: Next to the 3D image, MPRs are shown which were reconstructed with Vessel View on the display console of the Toshiba CT scanner. The software created two types of MPRs, the right MPR image were used for evaluation in this study. The 3D image shows the reconstructed coronary artery as a green line.*





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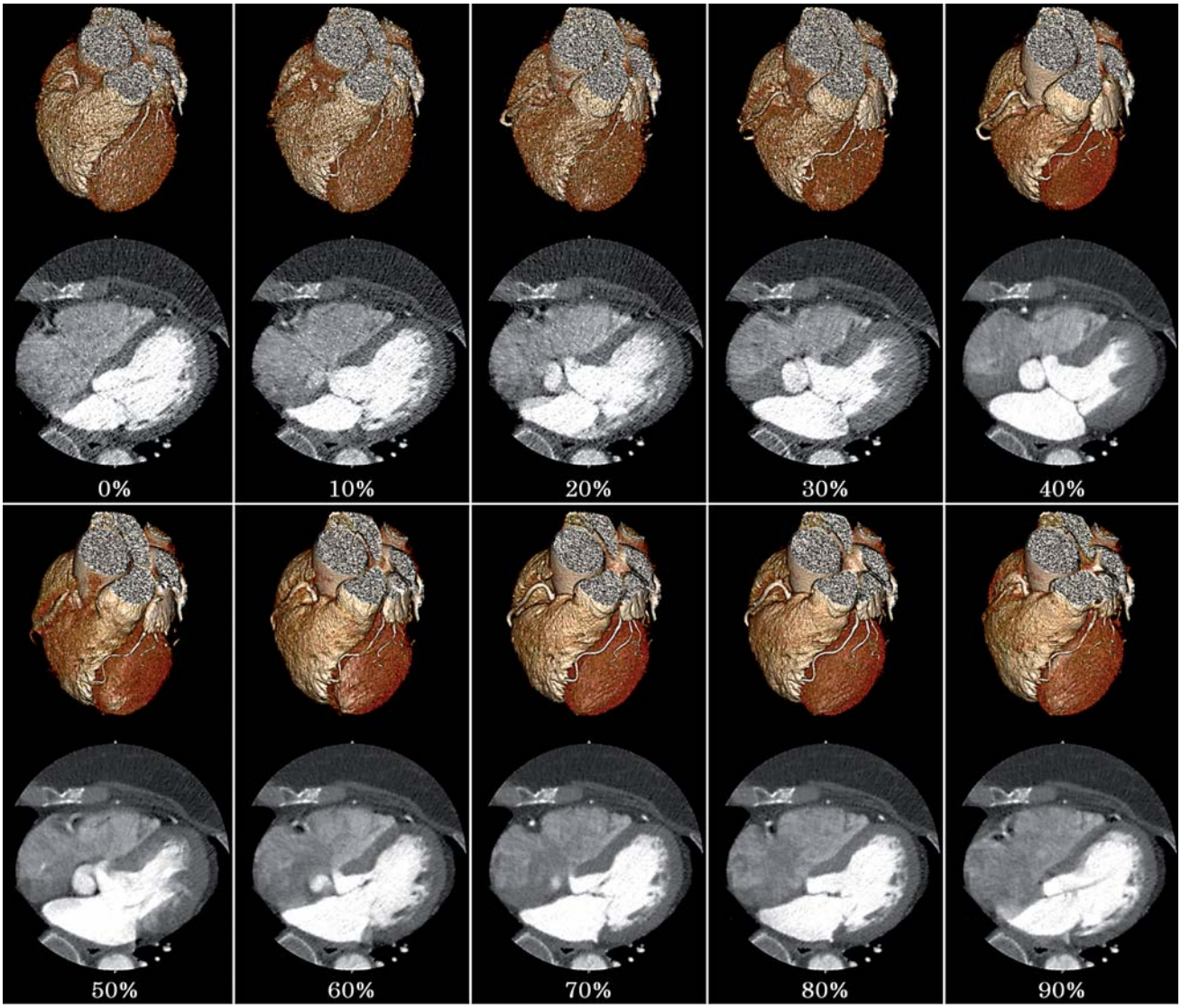


*Fig. 4: Image reconstruction of a 55-year-old female patient with heart rate of 57 bpm acquired on the Toshiba Aquilion ONE. For each cardiac phase with an interval of 10%, a 3D image reconstruction (upper image) and axial image (lower image) are shown. The cardiac phase with least motion is in this example 70%, but with smaller steps in the interval the optimal phase determination would be more accurate.*

Images were reconstructed at a 0.5 mm slice thickness and 0.3 mm reconstruction interval. The reconstructions were performed with a soft convolution kernel (FC11) in combination with a noise reduction filter and beam hardening artifact reduction filter (Quantum Denoising Software+ and Boost3D, Toshiba Medical Systems).

## Image analysis

The following three phase-selection methods for reconstructing the images were used.

**Predefined phase selection** – The best cardiac phase for CT coronary imaging was determined experimentally for patients with heart rates ≤ 65 bpm (20 patients) and for heart rates > 65 bpm (20 patients). This was determined by visual inspection of all cardiac phases at an interval of 5%. The phase at 75% after the R wave was observed to be the optimal phase for heart rates ≤ 65 bpm; however, for heart rates > 65 bpm, the optimal phase was 50% after the R wave. Based on the heart rate, one of these cardiac phases was used in the predefined phase selection method.

**Manual phase selection** – Manual selection of the best phase was achieved by visual inspection of multiple cardiac phases. Selection was performed by reconstructing one slice at the mid-ventricle level



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| Axial image evaluation | | All patients | ≤65 BPM | >65 BPM |
|---|---|---|---|---|
| **Mean ± SD** | Predefined | 2.69±1.09 | 1.98±0.76 | 3.40±0.88 |
| | Manual | 2.28±0.57 | 1.96±0.51 | 2.59±0.44 |
| | Automatic | 2.46±0.72 | 2.36±0.95 | 2.56±0.40 |
| **Mean difference ± SD** | | | | |
| Predefined-Manual | | 0.41±0.75 | 0.01±0.45 | 0.81±0.78 |
| Predefined-Automatic | | 0.23±1.10 | -0.39±0.94 | 0.84±0.89 |
| Manual-Automatic | | -0.19±0.71 | -0.40±0.80 | 0.03±0.54 |
| **Wilcoxon test (p-value)** | | | | |
| Predefined-Manual | | **0,005** | 0,864 | **0,001** |
| Predefined-Automatic | | 0,19 | 0,093 | **0,002** |
| Manual-Automatic | | 0,144 | 0,049 | 0,75 |
| **MPR image evaluation** | | **All patients** | **≤65 BPM** | **>65 BPM** |
| **Mean ± SD** | Predefined | 2.13±0.46 | 1.91±0.38 | 2.35±0.44 |
| | Manual | 1.92±0.35 | 1.95±0.37 | 1.88±0.34 |
| | Automatic | 1.95±0.45 | 2.14±0.47 | 1.76±0.34 |
| **Mean difference ± SD** | | | | |
| Predefined-Manual | | 0.22±0.69 | -0.04±0.59 | 0.47±0.70 |
| Predefined-Automatic | | 0.18±0.84 | -0.23±0.77 | 0.59±0.71 |
| Manual-Automatic | | -0.03±0.66 | -0.19±0.75 | 0.12±0.52 |
| **Wilcoxon test (p-value)** | | | | |
| Predefined-Manual | | 0,091 | 0,746 | **0,011** |
| Predefined-Automatic | | 0,167 | 0,284 | **0,004** |
| Manual-Automatic | | 0,976 | 0,241 | 0,274 |

*Table 1: Mean scores and mean score differences for axial and multiplanar reformation (MPR) image evaluations*

that contained all three coronary arteries. At that level, all cardiac phases were reconstructed from R wave to R wave with 20 millisecond time intervals. This results for heart rate 60 bpm to 50 cardiac phases. If one level did not provide sufficient information, multiple levels were used.

**Automated phase selection** – Automated phase selection was achieved using a fully automated optimal phase selection algorithm for cardiac CT to reconstruct images with the least motion. The algorithm creates a raw data motion map by subtracting raw data from the corresponding raw data at a phase interval 4% earlier. The raw data motion map shows the degree of motion throughout the cardiac cycle. From the motion map, an accurate interpolated motion graph is derived (Fig. 2).

Next, the algorithm initiates reconstruction of the best motion-free phase. The optimal phase is determined within 4 seconds by the software. The software is part of the exam plan and no manual interference is needed from scan start to reconstruction result.

The three phase selection methods resulted in three volumes for each patient. The images of the coronary arteries were compared in two ways: by evaluating axial images and multiplanar reconstructions (MPRs) by four observers.

Axial images were evaluated in the axial viewing mode on a dedicated workstation (Vitrea 2, version 3.9, Vital Images). Observers assessed image quality and graded the image quality of the coronary arteries using a qualitative 5-point ranking (1 = high quality, 5 = low quality). Observers were instructed to express perceived differences in image quality between the three reconstructed volumes in these five grades even if the differences were small.

For multiplanar evaluation, MPRs were reconstructed on the display console of the CT scanner using a semiautomatic vessel detection tool (Vessel View, Toshiba Medical Systems). After detection of the central lumen line of the vessels, the software produced images in which the vessel was stretched along a straight line (Fig. 3). MPRs were made for each coronary artery, i.e. the right coronary artery (RCA), left anterior descending (LAD) coronary artery, and circumflex coronary artery. MPRs were evaluated according to a forced-choice criterion (3-point ranking). This criterion was applied to enhance scoring for small differences. Observers were asked to assign the MPR with the best (score 1), second best (score 2), and least quality (score 3) with regard to motion in the images. The full displayed length of each coronary artery, which included multiple segments, was assigned a single grade.

## Data analysis

The mean score of the four observers for each patient was determined for statistical analysis. These mean observer scores were compared on a pairwise basis using the Wilcoxon's signed rank test.



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## Results

Fig. 4 shows an example of the different cardiac phases during one cardiac cycle of a 55-year-old female patient with heart rate of 57 bpm acquired on the Toshiba Aquilion ONE. Image reconstructions were performed at an interval of 10%. These cardiac phases show least motion artifacts during 70% of the RR-interval. Smaller steps in the reconstruction interval would result in more accurate determination of the optimal cardiac phase.

In Table 1, the mean scores and ranges are listed for the phase selection methods. These values are averaged over all observers per patient per reconstruction technique. A summary, including the mean differences and p values for the pairwise comparison, is given in the same table.

**All patients** – When all patients are included, a trend is seen in both evaluation methods (i.e., axial and MPR) that show the best performance for the manual phase selection (lower mean score) followed by the automated phase selection. Comparison of predefined and manual phase selection showed a statistically significant difference in axial image evaluation ($p = 0.005$). In other comparisons, no significant differences were found.

**Patients with heart rates ≤ 65 bpm** – For patients with relatively low heart rates (65 bpm), the axial evaluation showed the lowest mean score (best image quality) for manual phase selection. In the MPR evaluation, the lowest mean score was found with the predefined method. However, no statistically significant differences were found in image quality between any of the three phase-selection methods.

**Patients with heart rates >65 bpm** – For patients with relatively high heart rates (>65 bpm), both evaluation methods (i.e., axial and MPR) showed the best performance for automated phase selection followed by manual phase selection. Automated phase selection resulted in statistically significantly better image quality compared with predefined phase selection for axial ($p = 0.002$) and MPR ($p = 0.004$) evaluations. Also, manual phase selection showed significant better image quality than predefined phase selection (axial image evaluation, $p = 0.001$; MPR evaluation, $p = 0.011$). Between the automated and manual phase-selection methods no statistically significant differences were found.

## Discussion

This study aimed to assess the effects of three different phase selection methods with 64-MDCT coronary angiography in clinical patients. Axial image evaluation of all patients showed for the manual phase selection method statistically significant better results compared with the predefined phase selection method. In other comparisons using all patients no significant differences were found.

Image reconstruction fixed at 75% of the R-R interval (during diastole) for patients with heart rates ≤65 bpm generally provides the image quality needed for diagnosis. However at higher heart rates the optimal phase often shifts to the systole (±50%)[7,8]. The 75% predefined phase-selection method is an easy, time-efficient reconstruction technique that can be applied to evaluate patients with low heart rates. For patients with high heart rates, more effort is needed to reconstruct motion-free images of coronary arteries and often multiple reconstructions are performed to select the best phase for diagnostic evaluation of the major coronary arteries. For these difficult cases, the automated phase-selection method has been proven to be a helpful tool that provides image quality comparable to that of the manual phase-selection method.

An explanation for the good performance of the automated phase selection method at high heart rates is that it calculates the phase with the least motion using the entire scanned region. With the manual phase selection method, this determination is performed at one or two slice levels but coronary artery segments with motion may fall beyond the selected slice levels and result in a less optimal phase than that selected using the automated method based on volume motion. Nevertheless, the manual method showed results comparable to the automated method for selecting the optimal reconstruction phase.

The automated phase selection method showed in all comparisons no statistically significant differences compared with the manual phase selection method. At heart rates >65 bpm it resulted in best mean score in the image evaluations. The practical benefits of the automated compared with the manual phase selection method are the ease of use, the fact that it is operator-independent and the potential time saving.

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# Double Slice Mode for CT Image Reconstruction

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Toshiba Medical Systems

## Introduction

In computed tomography (CT) several vendors have recently introduced technologies to improve spatial resolution in longitudinal direction. With coneXact™ an alternative technology has been developed which doubles the amount of slices per rotation without the drawback of half quanta for signal intensity per slice reading as reported for flying focal spot technique. As a result, partial volume effects are minimized leading to more detailed MPR images while maintaining superior low contrast detectability[1]. Below we will discuss this technology, which improves image quality in z-direction, looking at wrist and petrous bone diagnostics, using the CT scanner Aquilion™ /CX (Toshiba Medical Systems Corporation, Tokyo, Japan). Double slice mode with 0.5 mm thickness and 0.25 mm interval leads to improved detectability in this typical example of super-fine structures.

## Image reconstruction with double slice mode

coneXact, a reconstruction algorithm used with enlarged cone angles for volume scanning, is based on a three-dimensional filtered back projection[2].

Using the raw data from all projection angles, a volume is reconstructed from which theoretically an infinite number of axial images can be generated from their surrounding raw data as shown in Fig. 1. With an axial volume coverage of 32 mm (Aquilion /CX with 64x0.5 mm detector element rows) at the iso-center the advanced coneXact re-

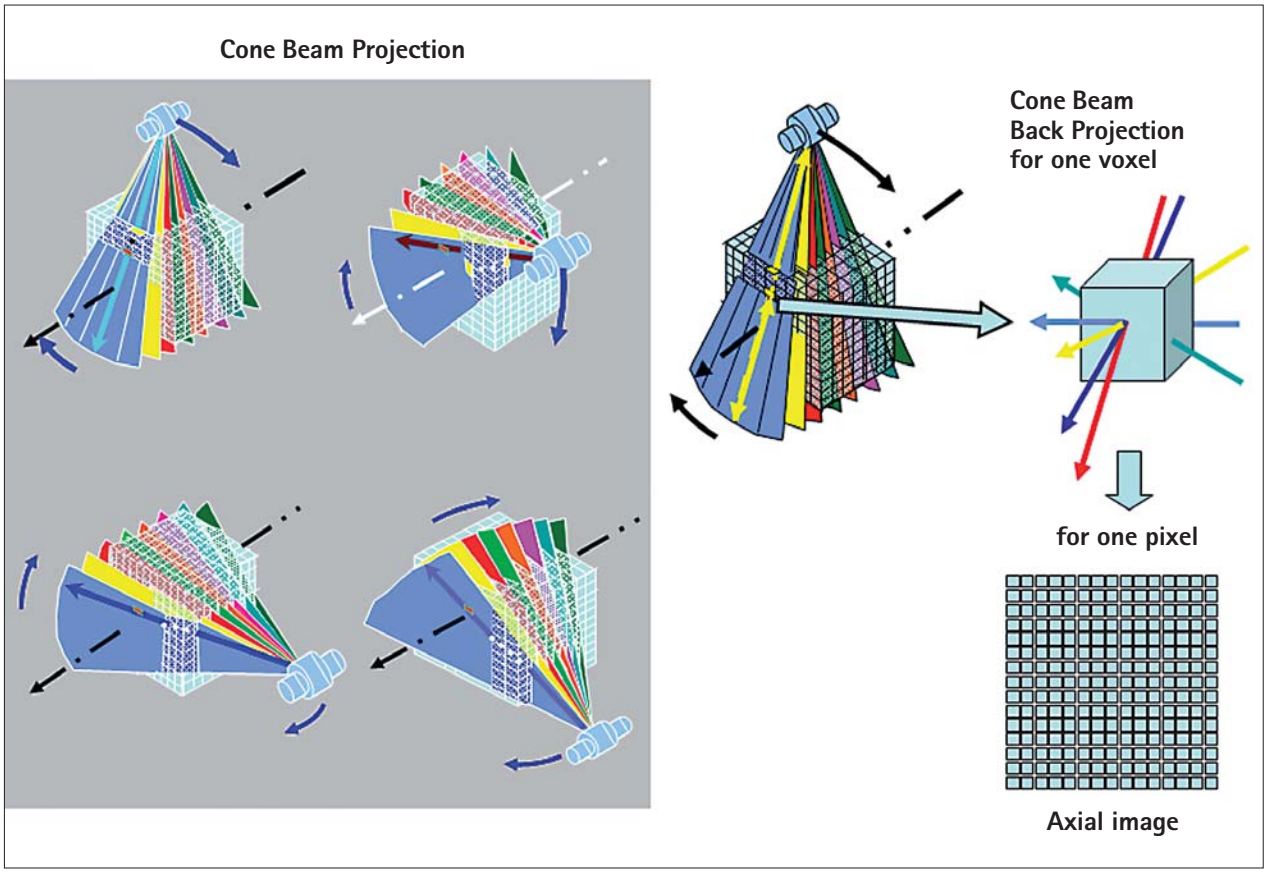


*Fig. 1: Principle of coneXact reconstruction based on matrix calculation with Aquilion /CX*



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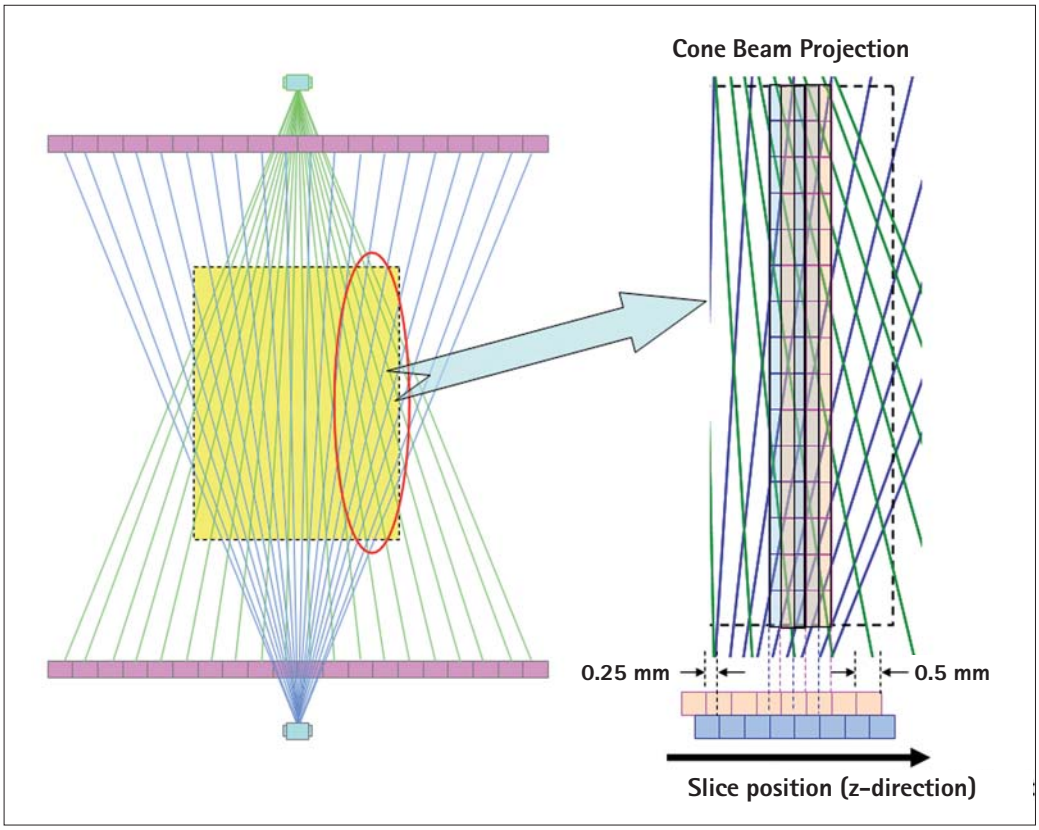


*Fig. 2: Principle of doubling the number of slice images with coneXact*

construction algorithm generates 128 unique slices per rotation with 0.25 mm interval (Fig. 2). Prior to image reconstruction from raw data, either standard mode and double slice mode can be selected, resulting in 64 or 128 slices.

## Results

### 1. Phantom testing

Phantom tests using clinical protocols were performed on a bore hole test pattern comprising rows of holes with diameters of 0.31-0.50 mm and hole-spacing of 0.30-0.49 mm. Size and spacing of the holes were confirmed by microscopy. For each row of holes, the average hole diameter and hole spacing were calculated (Fig. 3). After one gantry rotation with 120 kV and 75 mAs, a coronal slice image at identical positions was generated using standard mode (preset: 0.5-0.5) and double slice mode (preset: 0.5-0.25) from the same acquisition data. The window and level settings for the display were identical for both volume data sets. Both images were compared to conventional TCOT reconstruction with petrous bone helical scan acquisition protocol (120 kV, 75 mAs, pitch 0.64, 64 x 0.5 mm slices). All images were reconstructed with the standard organ-specific reconstruction kernel FC30 for minute osseous structures. Fig. 3a, 3b compare the lateral

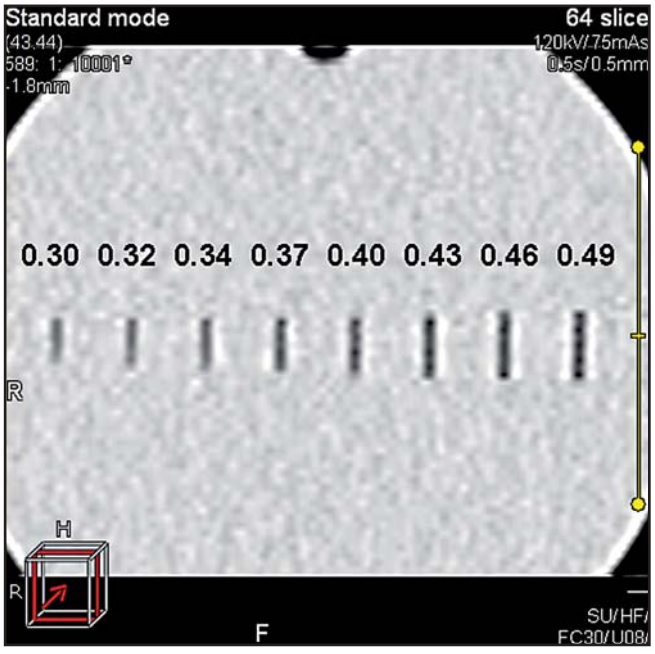


*Fig. 3a: Coronal test phantom slice image with 0.49 mm detectability in standard mode*



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detectability of the bore holes with standard mode and double slice mode after volume scan. Using the double slice mode the 0.34 mm diameter bore holes are resolved, compared to 0.49 mm of the standard mode this is a difference of approximately 44%.

Multi-slice helical scanning is considered to provide superior image quality compared to single-slice scanning due to a improved detail detectability along the patient's z-axis. To achieve high spatial resolution in a helical scan an overlapping pitch is required. With low pitch helical scan and TCOT reconstruction (0.5 mm slice thickness, 0.3 mm reconstruction interval), the bore hole detectability in the same phantom is 0.37 mm as shown in Fig. 3c. The difference in the lateral bore hole detectability between helical mode and standard mode is approximately 32%.

Image noise was measured in six regions in the identical coronal slice and ROI position. The average values in the 0.5 mm coronal slices were 23.4 HU in standard mode, 24.9 HU in double slice mode and 19.1 HU in helical mode. The difference in noise between volume and helical mode is caused by the difference in effective mAs (75 $mAs_{eff}$ vs. 117 $mAs_{eff}$). The $CTDI_{vol}$ values are 15.4 mGy and 25.0 mGy respectively, a 62% difference in favor of volume scanning.

Due to ethical restrictions on scanning the same patient twice, we compared the image quality of double slice mode (120 kV, 50 mAs, FC30, $CTDI_{vol}$ =10.3 mGy) and helical mode (120 kV, 40 mAs, pitch 0.64, FC30, $CTDI_{vol}$ =12.8 mGy) using an anatomical wrist phantom. Fig 4a and 4b demonstrate the improvement in detail sharpness with double slice mode using the FC30 reconstruction kernel.

In summary, the results from this bore hole and anatomical wrist phantom test under practical conditions confirm that the double slice reconstruction mode improves image quality.

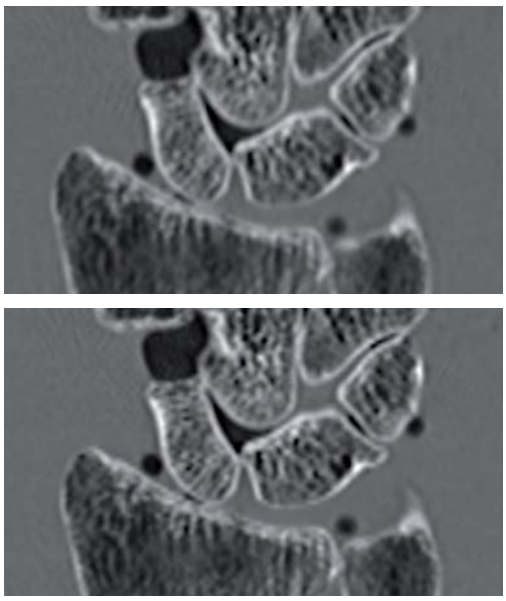

*Fig. 4: Coronal images of anatomical wrist phantom with helical mode (top) and double slice mode (bottom)*

## 2. Patient examples

Comprehensive assessment of the petrous bone structures requires high resolution image quality[3,4]. Thus structures should potentially be enhanced by the use of new CT system generations and their applied technologies to represent an adequate anatomical structure for image quality validation. In the first example the multi-planar reformation (MPR) images with standard mode and double slice mode of a patient petrous bone study (scan protocol: 120 kV, 75 mAs, DLP = 49.2 mGy*cm, E = 0.10 mSv with k = 0.0021 mSv/mGy/cm[5]) were compared. Reconstructions were performed with the high resolution

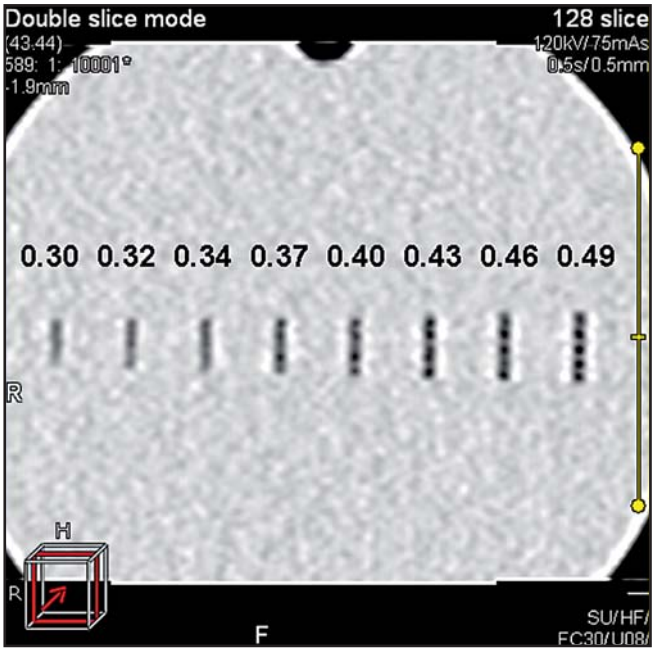


*Fig. 3b: Coronal test phantom slice image with 0.34 mm detectability in double slice mode*

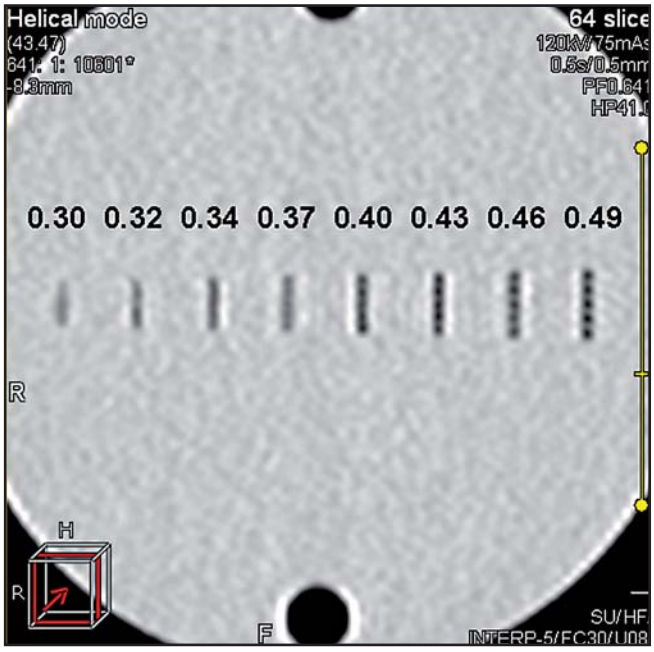


*Fig. 3c: Coronal test phantom slice image with 0.37 mm detectability in helical mode*



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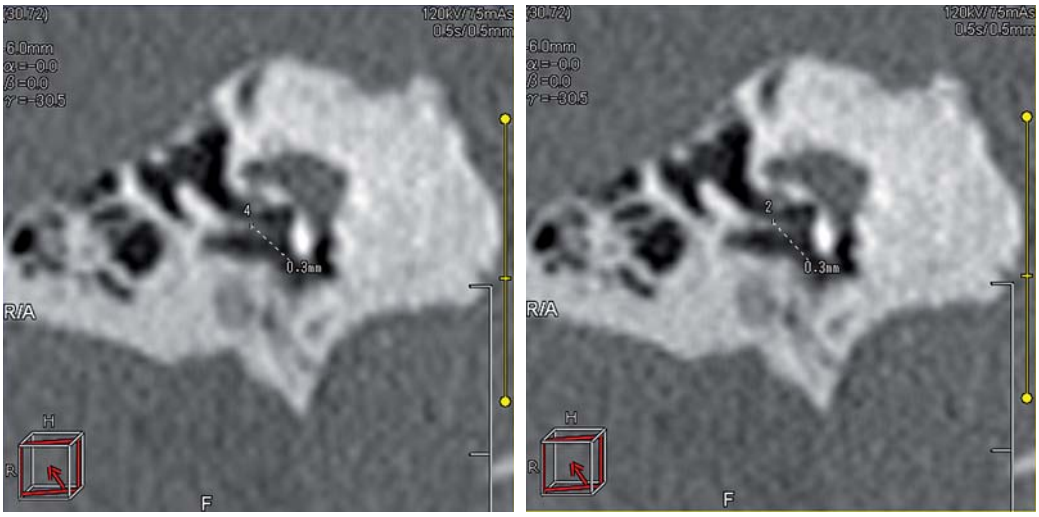



*Fig. 5: Comparison of stapes suprastructure with its measured limbs diameter of 0.3 mm with standard mode (left) and double slice mode (right)*

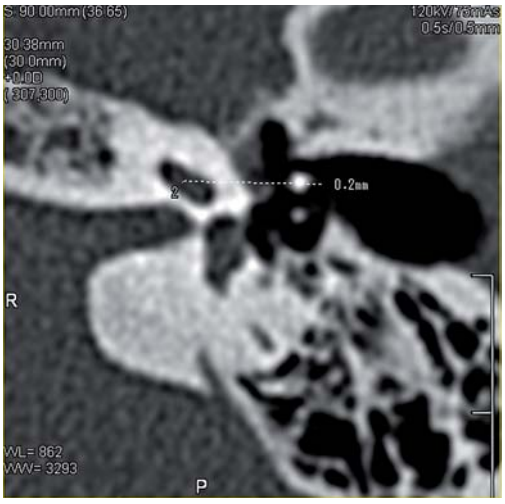
kernel FC30. All parameters for both reconstructions from the same volume data set were identical. Comparing the standard slice mode (Figure 5a) to the double slice mode (Fig. 5b), the stapes suprastructure with its measured limbs diameter of 0.3 mm are more detailed in Fig. 5b.

Using the same scan protocol and reconstruction kernel as above, a second example for double slice mode shows a measured anatomic interscalar septum diameter of 0.2 mm which is visualized as a sharp structure within its middle contrast range (Fig. 6). This shows the improved diagnostic potential in the detection of intralabyrinthine ossification.

## Summary

In bore hole phantom testing, the detectability of image reconstruction with double slice mode is improved, with a difference of ~44% compared to standard mode and of ~9% compared to helical mode. The coronal bore hole detectability obtained was 0.34 mm in double slice mode, 0.49 mm in standard mode and 0.37 mm in helical mode, using the clinical relevant kernel FC30 for these purposes. However, a special technical kernel leads to even higher spatial resolution. With the double slice capability of coneXact, the spatial resolution and image quality will improve, while for volume scan mode a significant lower dose is needed. The high lateral structure detectability of 0.34 mm bore holes ensures an adequate visualization of important pathoanotomic super-fine details, as shown by three examples of wrist, stapes suprastructure and interscalar septum. Imaging the petrous bone is a high-contrast diagnostic task, so it is reasonable to use a low effective patient dose of 0.10 mSv with coneXact reconstruction and double slice mode.

*Fig. 6: Interscalar septum with 0.2 mm diameter measurement (double slice mode)*

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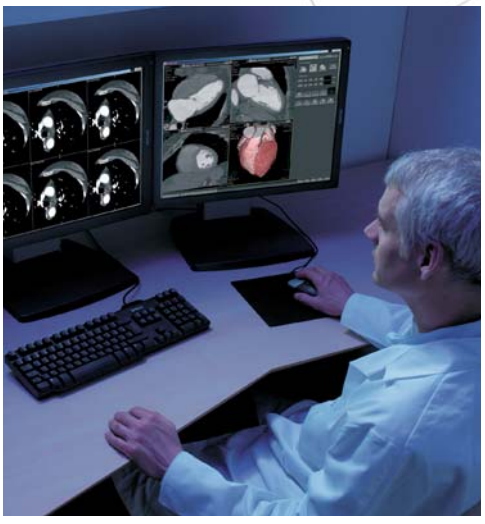

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# 3D Wall Motion Tracking – A new tool … , a new concept … and more time for you!

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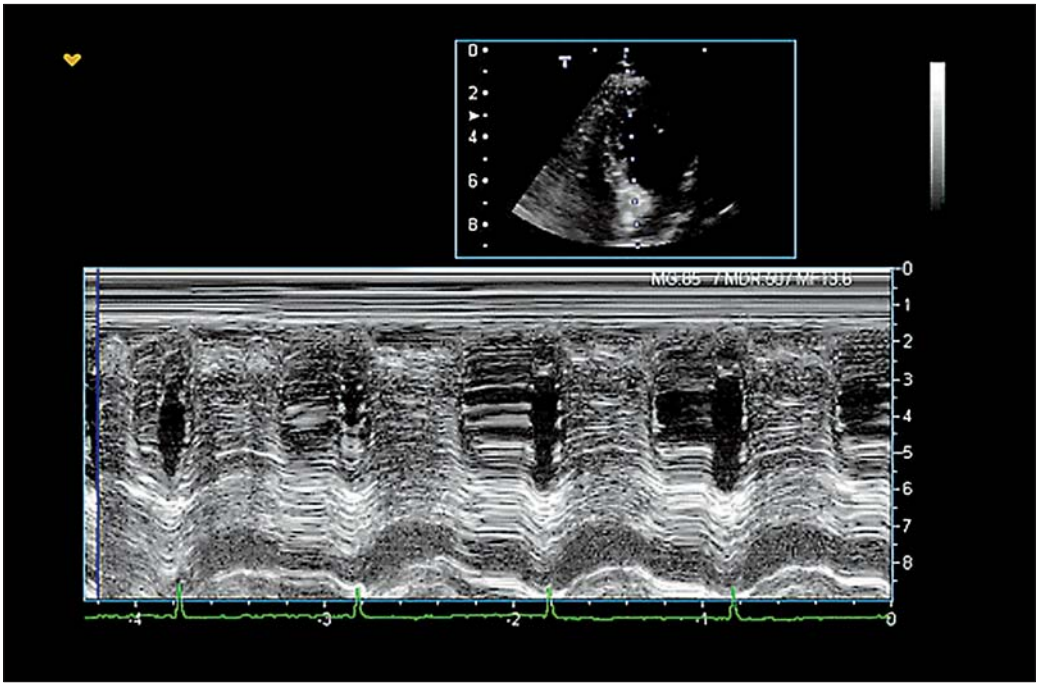
**Below, we would like to present a new diagnostic tool developed by Toshiba Medical Systems, Tokyo, Japan, and implemented in their new Artida system:** 3D wall motion tracking (3D WMT). This technology offers relevant advantages over other systems, namely a new way to analyze the left ventricle and a new concept to assess its function. Nevertheless, we would like to focus on one feature of this new tool: unlike other systems, 3D WMT is not time-consuming and is thus suitable for use as a routine analysis tool in daily clinical practice.

## What is wall motion tracking?

Speckle in ultrasound images is caused by interference of energy from randomly distributed scatterers, too small to be resolved by ultrasound technology. Speckle degrades both the spatial and the contrast resolution by creating fine false structures, the so-called speckle noise. Speckles have two crucial features: firstly, each structure in the body has a unique speckle pattern and secondly, speckles move with the tissue (Fig. 1). Wall motion tracking (WMT) exploits these features by recognising the identifying speckle pattern of each region of the myocardium and following its displacement.

Strain and strain rate are parameters obtained from tissue Doppler data[2]. WMT technology offers a new and more direct approach to determine these values. 2D WMT analyses the displacement of a myocardial region (Fig. 2) in order to calculate circum-

*Fig. 1: Left ventricular wall M-mode shows how speckle moves with tissue.*





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ferential, radial and longitudinal strain[3-5]. Furthermore, other parameters such as rotation, shear, twist and torsion can be evaluated. WMT-derived strain and strain rate provide clinically relevant information in a huge number of cardiac diseases.

## Do I need 3D WMT?

The interpretation of echocardiography requires mental integration of different planes. Consequently, 3D more closely represents reality than 2D. The heart has three dimensions, cardiac motion is 3D and speckle noise moves in the three spatial directions. 2D WMT is limited because it cannot assess movement in the third dimension: since 2D WMT follows wall motion in a 2D plane, only a portion of the real motion can be detected. This is where 3D WMT comes in: the new 3D WMT technology enables us to follow speckle in the three spatial directions and to assess real 3D movement. 3D WMT is a new tool that combines the usefulness of WMT with improved integration of the heart structures (Fig. 3).

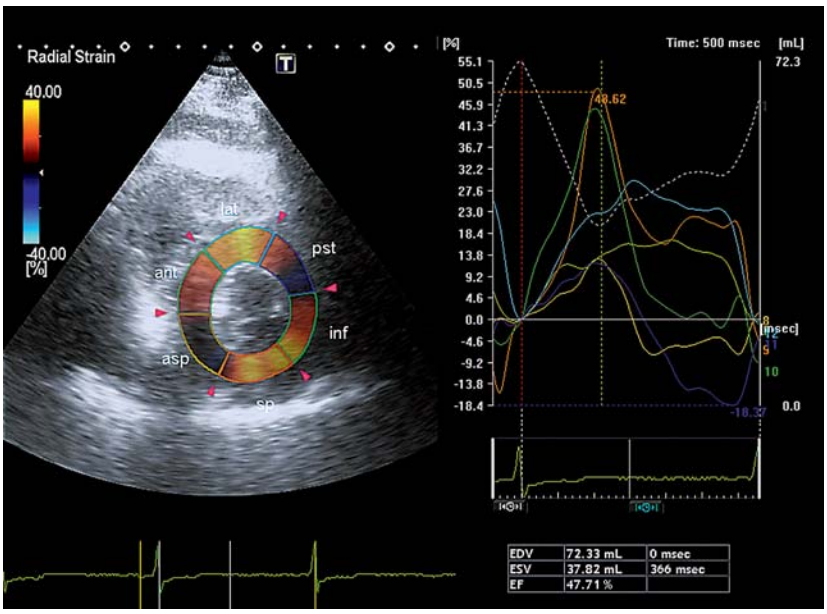


*Fig. 2: Left ventricular 2D WMT evaluation. The analysis of a short axis view is shown. The analysis of the whole left ventricle is very time-consuming.*

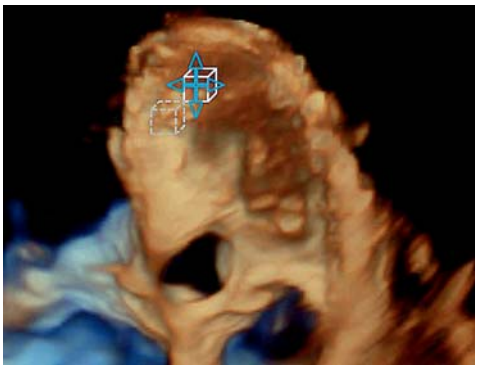

*Fig. 3: 3D WMT uses a box-template to detect speckle motion in three dimensions.*

**Do I need a very good acoustic window to use 3D WMT?**

The new 3D WMT system works well with medium-quality echocardiographic images. In a recently published study, only two patients out of 30 were excluded because of poor acoustic windows[6]. Furthermore, the results of that study show that the 3D probe can acquire a more complete analysis because the entire left ventricle can be analyzed from a single apical position and the sonographer does not need to change position to obtain different planes. In short: 3D WMT can assess more myocardial segments than 2D WMT regardless of whether a patient had a good or bad transthoracic window.

**How should I do a 3D WMT study?**

The new Artida system and the PST-25SX 1-MHz to 4-MHz phased-array matrix transducer (both by Toshiba Medical Systems, Tokyo, Japan) are required to carry out a 3D WMT study. These two components optimize 3D image acquisition. The matrix transducer scans a user-selected volume that can be adjusted from 15° x 15° to 90° x 90°. For real-time purposes, a one-beat acquisition is used and for advanced analysis, a triggered acquisition mode is selected. In the triggered mode (the mode used for 3D WMT evaluation), a live monitoring mode allows the user to monitor the reconstruction of the full-volume data set. The standard application setting uses four subvolumes of 90° x 22.5°, which results in a 90° x 90° triggered full volume in four heart cycles. During the acquisition, a five-plane view of the four- and two-chamber apical views and short axis planes at apex, mid and base of the LV is guiding the user to keep the best transducer position and updates the acquisition process continuously. During acquisition, matching of the sub-volumes, which can be monitored on the screen, is crucial. If a mismatch occurs, the examiner can continue the acquisition process until the mismatch disappears in later heart cycles which are shown on the monitor. A retrospective acquisition method is used and after 'freeze' the best full-volume datasets can be selected from the image memory. A template for the B and C planes is available to orientate the A, B and C planes in order to achieve the best possible plane selection.

Each 3D data set is displayed in a five-plane view: (A) an apical four-chamber view; (B) a second apical view orthogonal to plane A; and (C) three short-axis planes: plane C1 in the apical region, plane C2 in the mid-ventricle and plane C3 at the basal portion of the left ventricle. The user then sets three markers on planes A and B; in each plane, one marker is set at the apex and the other two at the edges of the mitral valve ring. The software then detects the LV endocardium and the user sets a default thickness for the myocardium (Fig. 4). The software automatically splits the LV into 16 or 17 segments as suggested by ASE and AHA respectively. After the markers have been selected, the system performs the 3D WMT analysis through the entire cardiac cycle. The selection of the LV shape is semiautomatic and



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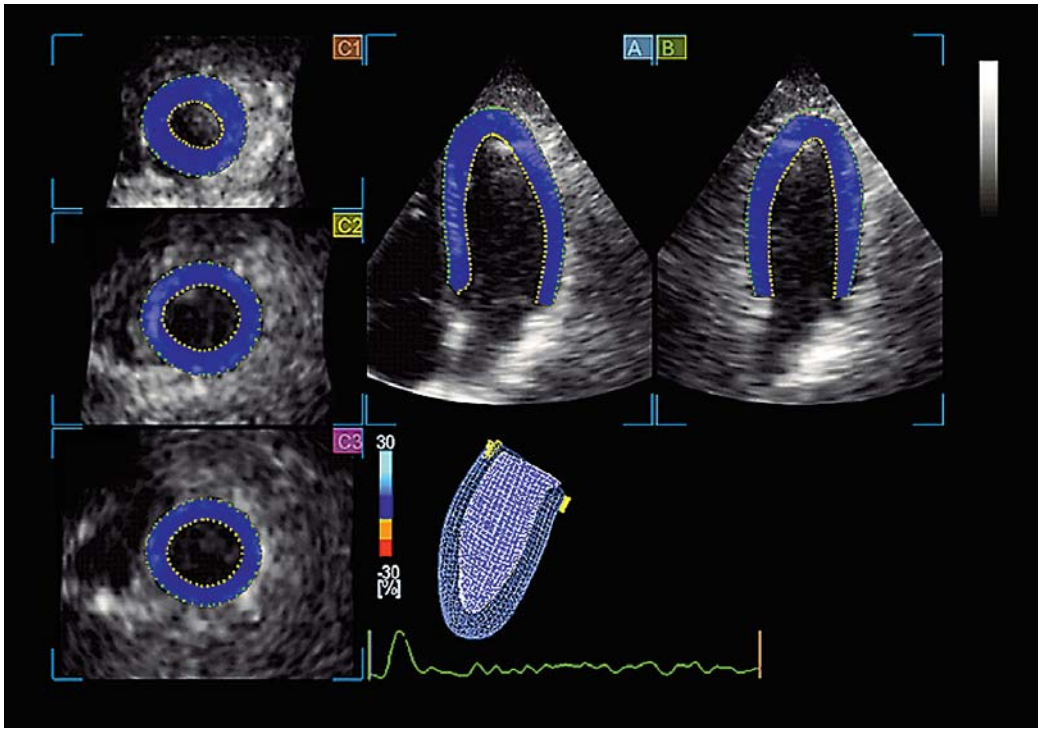


*Fig. 4: Left ventricular semi-automatic tracking. The user sets three markers in planes A and B. The software then detects the LV endocardium and the user sets a default thickness for the myocardium. See text for more details.*

the tracking process is automated, but the user can adjust the results of the tracking process when needed. Finally, the results of the 3D WMT analysis are presented as averaged values for each segment.

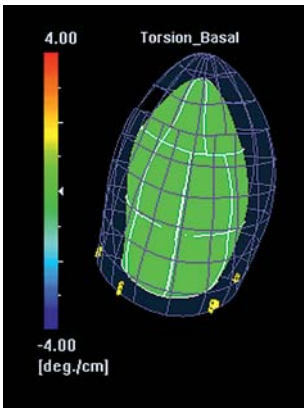


*Fig. 5: The patient presented with dilated cardiomyopathy and severely depressed left ventricular ejection fraction. The selected display shows the results of the analysis of the left ventricular torsion in the so called "plastic bag" view.*

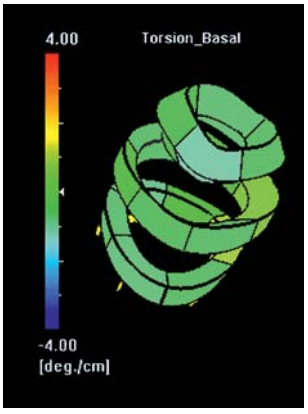


*Fig. 6: The same patient as above. The selected parameter is again the left ventricular torsion, but the selected display is the "doughnut view".*

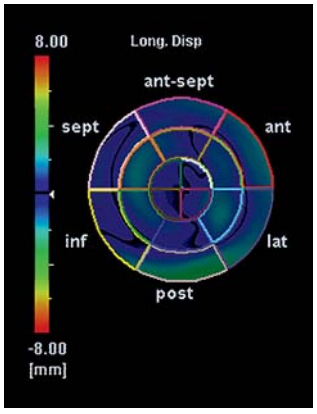


*Fig. 7: Another type of display is the "dynamic polar map".*

**How does the system display the 3D WMT analysis results?**

The 3D WMT analysis results can be displayed in different ways, for example the so-called "plastic bag" (Fig. 5), the "doughnut view" (Fig. 6) or the "dynamic polar map" (Fig. 7). The user can choose among many different displays and all data may also be obtained in numeric format.

**Is 3D WMT time-consuming?**

Saving time is one of the main advantages of 3D WMT. The Artida system equipped with 3D WMT provides a very fast analysis of both the global function and the regional function of the left ventricle. Moreover, this tool allows you to perform the analysis in every patient in your daily work. Within 20 seconds, the result of 3D WMT is available offering a broad range of parameters describing myocardial function. Different parameters such as displacement and strain in longitudinal, radial and circumferential orientation are provided in addition to the 3D vector-based variants. Further parameters such as twist and torsion are selectable based on rotation information which is also available as a display parameter.

The results of the above-mentioned study[6] furthermore show that not only can 3D WMT assess more myocardial segments, but data can also be acquired and analyzed in less time. The acquisition and analysis of the data sets is easy and fast. Within a few minutes we can obtain



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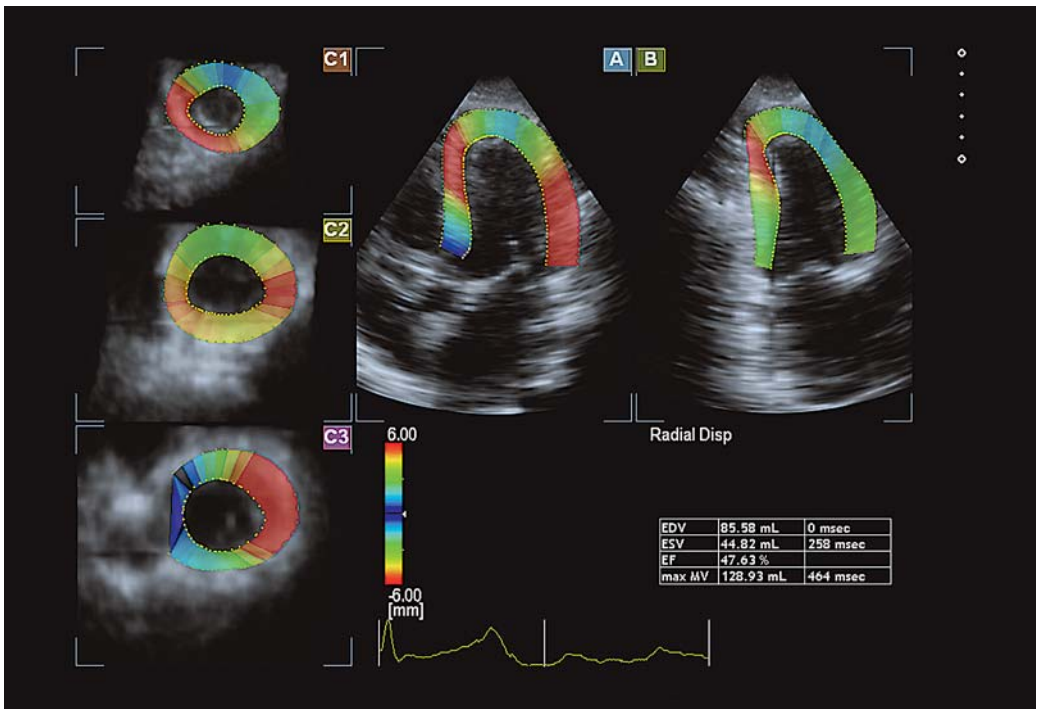


*Fig. 8: Automatic calculation of left ventricular volumes and ejection fraction based on 3D WMT technology. The system automatically displays this information together with the wall analysis.*

several parameters such as strain, rotation, twist and torsion of every cardiac segment derived from the 3D data set. This new technology provides a fast and global approach to the analysis of these parameters and avoids its under-use due to the time-consuming nature of 2D-derived speckle technology. Average study times for 2D and 3D WMT are shown in table 1.

**And ... what about variability?**

Inter- and intraobserver variability is not a problem with the new 3D WMT system. A recently published article[6] shows good interobserver agreement for radial and longitudinal strain measurements on 3D WMT: the intraclass correlation coefficients were 0.79 and 0.81 for the measurements of radial and longitudinal strain respectively and similar results were recorded for intraobserver agreement analysis (the intraclass correlation coefficients were 0.91 and 0.85 for radial and longitudinal strain, respectively).

**Does the system provide any other information?**

Definitively yes. The new Artida system and the 3D WMT analysis not only provide information regarding the segment analysis of the left ventricular myocardium but they also provide a robust evaluation of LV volume during the heart cycle. The detection of the endocardium for wall motion purposes is also useful to obtain the inner dimensions of the LV 3D shape and the myocardial volume. Thus, the system also provides information regarding LV volumes and LV ejection fraction, and the related volume curves are presented time-aligned with the segmental parametric imaging curves. The detection of the endocardium is based on 3D tracking information and not on 2D plane assumptions. The 3D shapes can be corrected by the user when needed in five orthogonal planes. Thus, the assessment of the LV volume is anatomically correct and robust and offers reproducible calculations of LV volumes and ejection fraction (Fig. 8).

| | 2D WMT | 3D WMT |
|---|---|---|
| Acquisition time in minutes | 4.1 | 1.7 |
| Analysis time in minutes | 9.9 | 3.3 |

*Table 1: Comparison of average times required for data acquisition and LV analysis with 2D and 3D wall motion tracking[6]*

**Which are the applications of this new tool?**

3D WMT is a new tool which has demonstrated its usefulness in several clinical scenarios. It is promising with regard to the evaluation of different heart diseases such as dilated cardiomyopathy, left ventricular asynchrony evaluation or ischemic heart disease.

## Conclusion

3D WMT is a new technique that can quickly and completely assess global and regional left ventricular function. It is a potential clinical bedside tool for quantifying global and regional left ventricular function and it may help the clinician save time without having to forego a complete and accurate analysis.

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**Ultrasound is rapidly turning into the clinician's "new stethoscope". Unlike the good old low-tech stethoscope, however, ultrasound equipment needs to be highly portable and at the same time offer state of the art technology.** If that sounds like squaring the circle – Eureka! – Toshiba's engineers did it: Viamo combines all the advantages of a compact ultrasound system with the diagnostic precision, comfort and ease of use of a cart-based machine. Sharing its core imaging engine and transducer technology with Toshiba's premium ultrasound platform Aplio XG, Viamo integrates clinically proven imaging features such as Pulse Subtraction or QuickScan to provide uncompromised Toshiba image quality and Doppler sensitivity.

## Touch screen

"The screen clearly is the Viamo's 'pièce de résistance'; the manufacturer has revolutionised ultrasound scanners and provided us with an impressive touch screen panel. This not only simplifies the keyboard but makes this laptop extremely user friendly", says Dr Adrian K P Lim of Imperial College, London, who thoroughly tested this pioneering product in a clinical setting.

Viamo's screen can be rotated 270 degrees further enhancing the already excellent ergonomics of the scanner. When fully turned and folded flat, the system can be operated in tablet mode solely via its touch screen. Individual key functions on the console and touch screen are user programmable to suit the user's specific diagnostic requirements or personal preferences. In short: the touch screen allows for seamless workflow and an outstandingly comfortable and intuitive operation of the system.

"The VIAMO
*is a well designed portable scanner, with the touch screen panel being a revolutionary feature. Grey-scale imaging and Doppler sensitivity are extremely good."*

*Dr Adrian K P Lim, Imperial College, London*



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## Transducers

A dedicated series of Aplio XG transducers with small form factor connectors is available. Moreover, Viamo can connect Aplio XG specialty transducers with standard connector via a cart-mounted transducer connector.

The lightweight, battery-powered system is up and running within just a few seconds, making it instantaneously available also in critical situations. The laptop-sized Viamo can be hand-carried or operated on its height-adjustable and easy to manoeuvre stand - very useful in cramped hospital quarters lacking the working space to park the laptop.



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# Area Tracking – A new parameter using 3D wall motion tracking

W Gorissen
Toshiba Medical Systems

## Background

Area Tracking is a new parameter of regional and global LV function provided by 3D wall motion tracking (3D WMT) on the ARTIDA premium class ultrasound system from Toshiba Medical Systems.

3D wall motion tracking is based on the 3D speckle tracking technique and provides various parameters using a full volume dataset of the heart obtained over four or six heart cycles or by a one-beat acquisition.

The advantage of this method is that all segments of the LV can be analyzed in their anatomical relation to each other and that the acquisition is much faster than acquiring 2D planes covering the heart individually.

Based on a full volume dataset of the LV, 16 or 17 segments according to ASE or AHA standards are defined automatically. In each of these segments, hundreds of speckles are tracked and the results are displayed in a graphical plot. The basic information of speckle tracking is 'displacement' and from this information, various parameters, like real 3D strain, longitudinal and circumferential strain, twist and rotation can be calculated.

For LV function strain parameters are important because they reflect myocardial thickening or shortening. In 3D speckle tracking, longitudinal and circumferential strain are very stable and reproducible parameters and can be used for your clinical routine application.

## What is Area Tracking?

To assess thickening of the myocardium in all segments real 3D strain can be used to provide the appropriate information in all segments. However, in daily routine tracking of both endocardial and epicardial speckle signals can be limited by the quality of the data due to limited image quality in some patients who are difficult to scan.

Area Tracking based on 3D wall motion tracking reflects the 3D radial strain and is based on endocardial changes only, which makes the method very sensitive for detecting ischemic reactions in the myocardium which are most detectable in the subendocardial layers. Area Tracking reflects the deformation of the endocardial surface during LV contraction and relaxation.

Since an area is the product of length and width, Area Tracking can be considered a combination of longitudinal and circumferential tracking.

A segment of the LV will change in shape during the cardiac cycle. The inner endocardial surface will decrease in systole due to longitudinal shortening (longitudinal strain) and circumferential shortening (circumferential strain) myocardial thickness will increase (radial strain).

Since the myocardial volume (or LV mass) is constant during the cardiac cycle, the Area Tracking curve x radial strain = constant. The Area Tracking value will be the inverse of the thickening which is reflected by 3D radial strain.

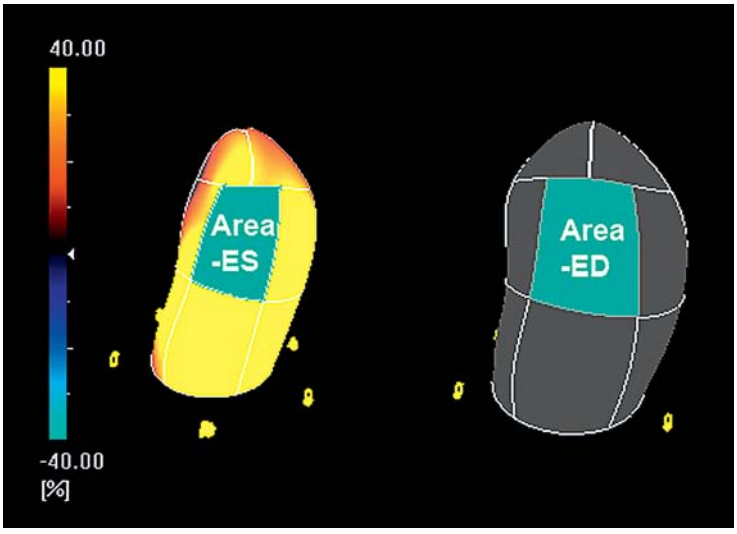


*Fig. 1: Endocardial surface area change of the mid-posterior segment in a normal heart*



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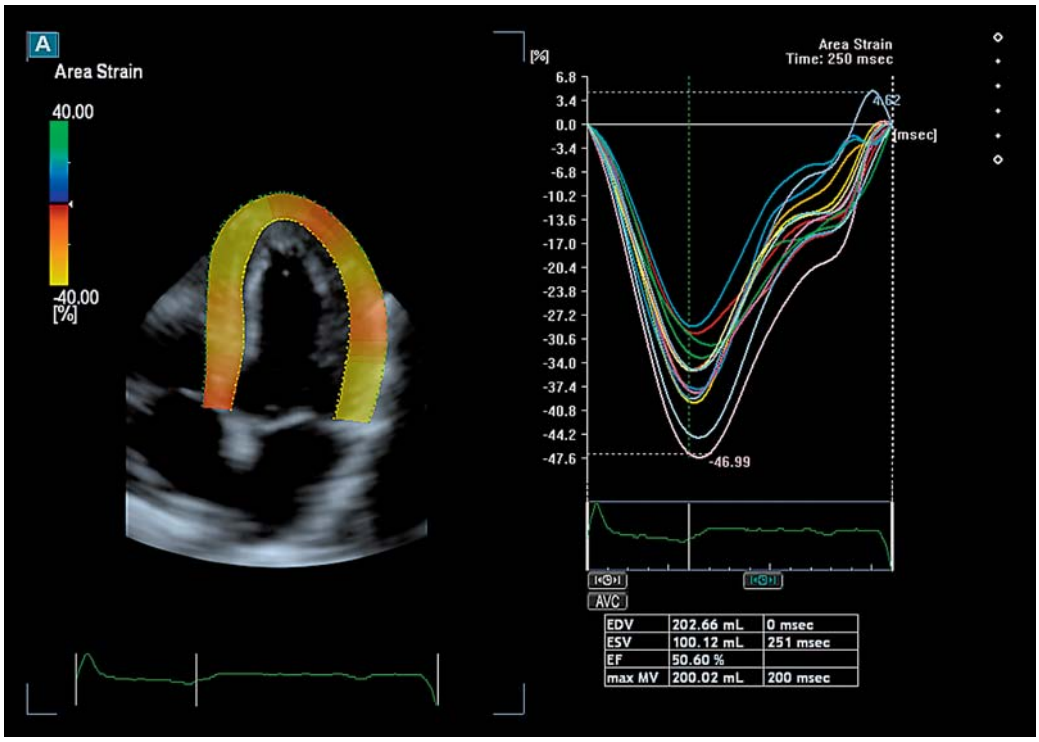


*Fig. 2: Area Tracking in normal heart*

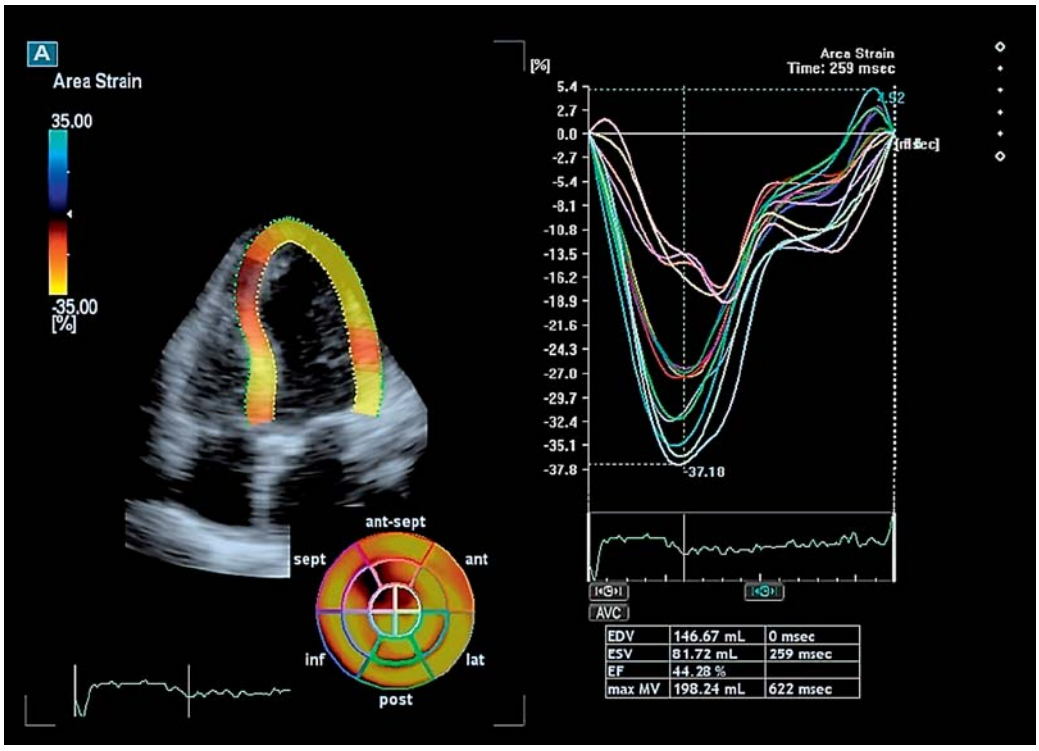


*Fig. 3: Area Tracking in case of an anterior infarction*

### Global Performance Plot*

In order to present the outcome of a 3D WMT analysis, several parameters can be combined in a graphical display to facilitate readout of the contraction components. One example that is used for research purpose is the GPP (Global Performance Plot). In this plot the peak value of the global Area Tracking based on all 16 segments is combined with the Standard Deviation Index (SDI) as presented by the group of M Monaghan (S Kapetanakis et al). In this case the Standard Deviation Index reflects the time-to-peak Area Tracking related to the heart cycle. In a normal heart, we find a global Area Tracking value of around 40%, where the SDI is typical below 5%. In case of ischemic heart disease, the global value will decrease where the SDI will increase.

## Applications

Area Tracking can be calculated per segment, but it can also be displayed as a global LV parameter so it can be used in a variety of situations where it can add clinical diagnostic value to existing routine.

*works-in-progress, available for research now



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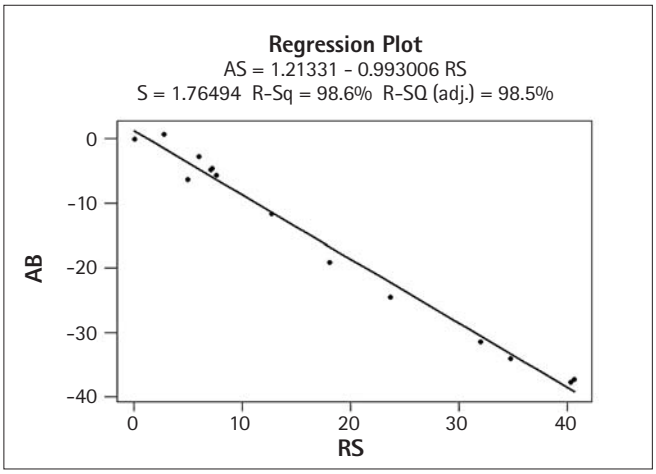



*Fig. 4: An example of Area Tracking (or strain, AS) and radial strain relation in a normal individual measured with the Artida system. It reflects the close correlation between Area Tracking (AS) and radial strain (RS).*

### Routine echocardiography exams

Since reproducibility and robustness are high and can be applied to one-beat 4D acquisitions, Area Tracking can be integrated easily into routine echocardiography studies.

### Stress echo

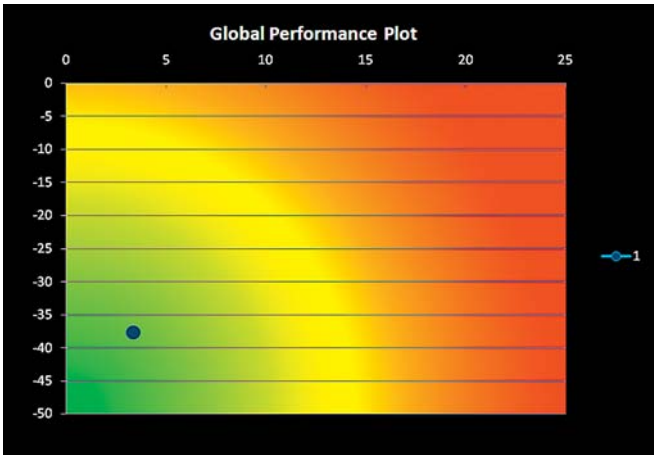
Since Area Tracking is based on endocardial changes which are highly sensitive for ischemic reactions in the myocardium, the application in combination with stress echo is a very promising tool to quantify stress echo readings.

### Cardiac resynchronization therapy

Since Area Tracking is quite easy to use and robust and sensitive for dyssynchronous wall motion, it facilitates detection of dyssynchrony and can be used in the selection of patients for CRT. Also in the localization of delayed contracting segments and optimization of CRT devices, Area Tracking promises an easy and fast method to optimize the timing of the lead delays. Initial work is in progress to study the advantages of the method for this application.

## Conclusion

Area Tracking, a promising new parameter for clinical echocardiography routine, provides global and regional function simultaneously with the LV volume and ejection fraction. Applications in relation to screening and follow-up of patients with ischemic heart disease or CRT are being evaluated. Stress echo Area Tracking has the potential to provide objective parameters to evaluate stress echo data.



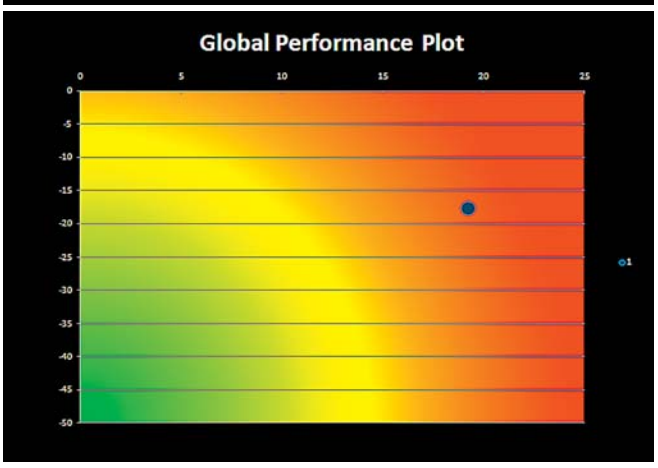




*Fig. 5: An example of the Global Performance Plot (GPP) based on Area Tracking in a normal individual . The typical normal plot shows a high Area Tracking value (38% area change) combined with a low SDI of (3%).*

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*Fig. 6: In case of dyssynchrony (on the right), a reduced Area Tracking value is found in combination with a high SDI value.*

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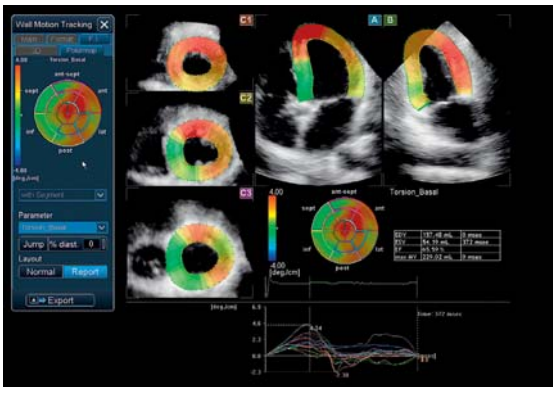


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# Elastography of the Prostate in the Detection of Prostate Cancer

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University Hospital of Wales, Cardiff, United Kingdom

## Introduction

This paper presents initial experience with a new Toshiba elastography imaging system used to detect prostate cancer. Since this is a preliminary evaluation, the elastography imaging procedure was performed in addition to our standard procedure of ten systematic biopsies, plus extra biopsies of suspicious areas where appropriate. The elastography images did not influence the biopsy pattern and the elastography findings were subsequently compared with tumour detection on the biopsy cores (all cores are labelled separately) and with radical prostatectomy specimens where available.

The number of patients studied is not yet sufficient to present hard data, but the following initial impressions of the procedure, illustrative case reports and discussion of the possible role of elastography in the detection of prostate cancer may provide a starting point for further studies.

## Background

With patients showing a high serum prostate specific antigen (PSA) level and/or an abnormal digital rectal examination there is a high probability (40–66%) of clinically significant prostate cancer.

The standard method to detect prostate cancer in these patients is to perform multiple biopsies of the prostate obtained in a set pattern throughout the gland which also allows for histological (Gleason) grading of any cancer detected.

There are, however, certain problems with this procedure:

1. It is invasive and unpleasant. Multiple biopsies – at least eight or ten – are necessary. Repeat biopsies for a rising PSA level and a negative initial set of biopsies require more than ten biopsies.
2. A proportion of cancers will be missed (false negative tests). The number of false negative tests is difficult to determine as there is no gold standard, but based on positivity rates on second or third biopsies the rate may be between 10 and 33%.
3. Increasing the number of biopsy cores obtained increases positivity rates but also increases the number of "clinically insignificant" tumours found. These are small, low grade tumours that, evidence suggests, are unlikely to progress to clinically significant tumours.
4. The size of a detected tumour can be estimated from biopsy data, i.e. the number of cores involved and the length of tumour in each core. The estimate is often inaccurate because the biopsy core may just detect the edge of a large tumour and a tumour may be multi-focal.

Because of these disadvantages attempts are being made to visualise tumours on the ultrasound image so that biopsies can be targeted to the tumour. Greyscale ultrasound and colour Doppler studies, however, are disappointing. More recently, contrast-enhanced ultrasound and elastography imaging are being studied.

If prostate cancer could be imaged with a method that produces a high negative predictive value then patients with negative imaging would not need biopsies. So far, no imaging method has achieved this objective and even from an unbiased point of view it seems unlikely that elastography imaging can close this gap.

There are, however, some limited, but nevertheless very important goals that may be achieved.

1. Adding elastography-guided biopsies to the standard biopsy regime may increase positivity rates (reduce false negative results).
2. If a tumour is visualised, diagnosis can be supported by targeting the abnormal area with fewer biopsy cores than conventional biopsies.
3. The size of the tumour may be more accurately estimated and it might be possible to distinguish significant from insignificant tumours.

## Technique

The elastography system features a split screen with one screen showing a conventional greyscale image, while the other one visualizes movement using colour Doppler. This is so to speak the basic real-time elastography image.

The greyscale image allows positioning within the prostate gland. The gland is then compressed and allowed to relax by applying 3 or 4 simple "flicks" of the transducer at about 1–2 second intervals. This produces the data for the more sophisticated strain imaging.

The colour Doppler "elastography" image enables gain adjustments which optimise the elastography image. Although the colour Doppler elastography image is inherently inferior to the strain images, it is a real-time image which means if any suspicious areas are detected, the image plane to study these can be accurately determined.



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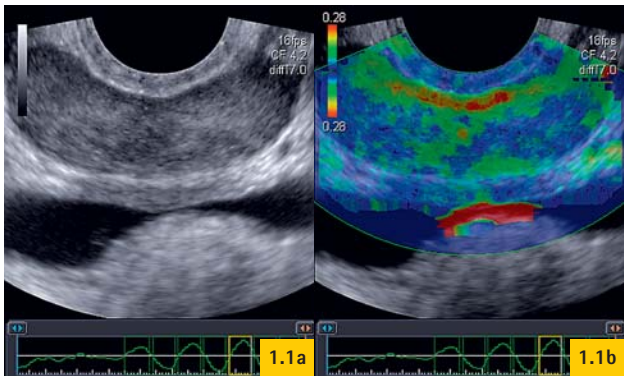


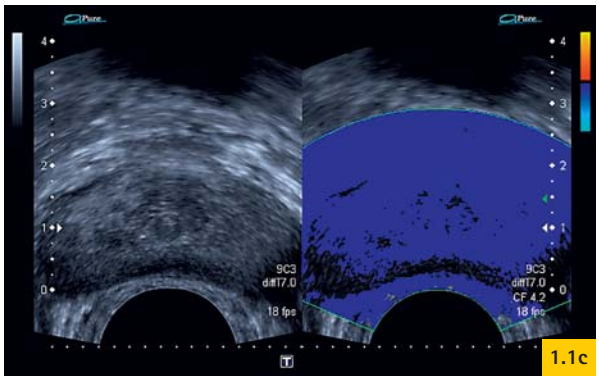


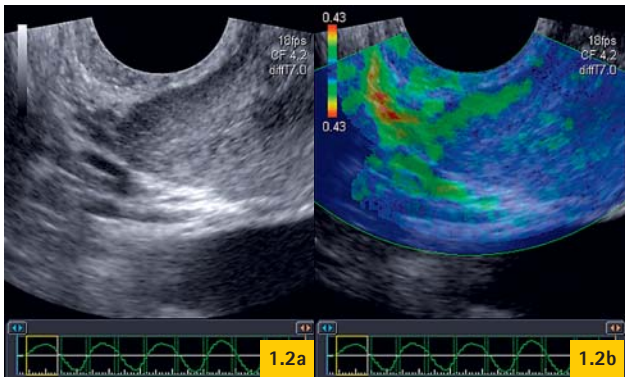


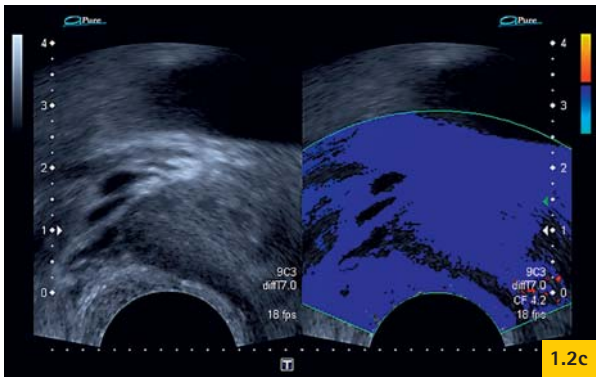


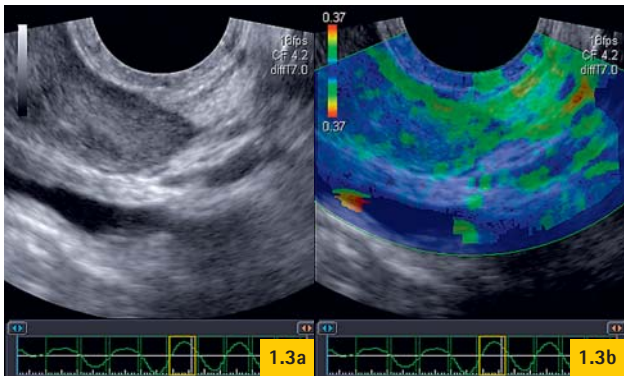


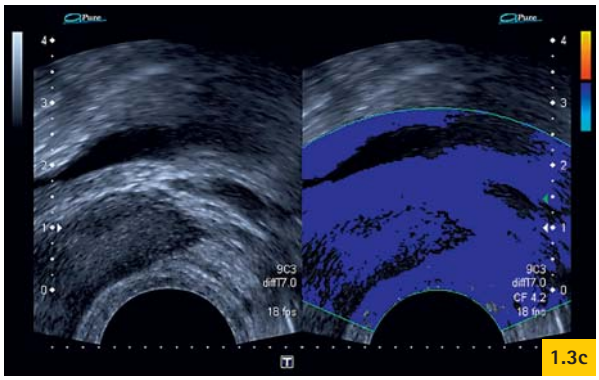


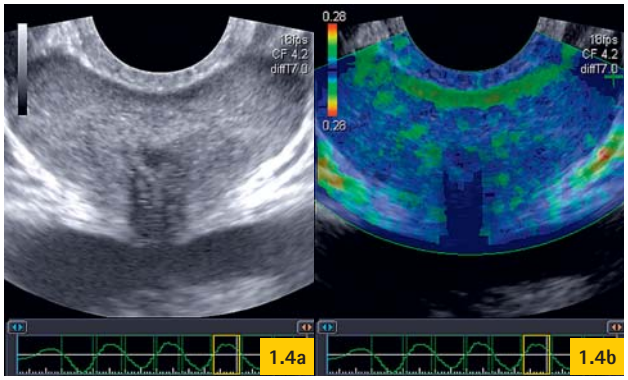


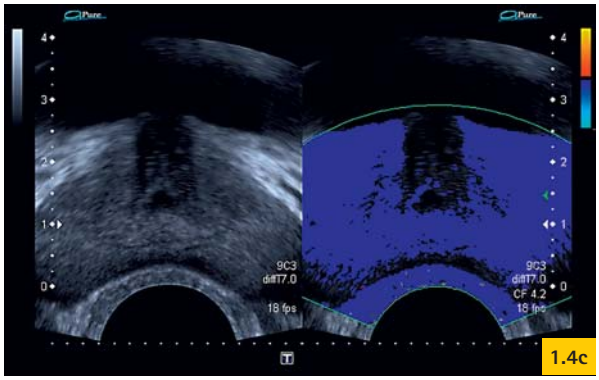


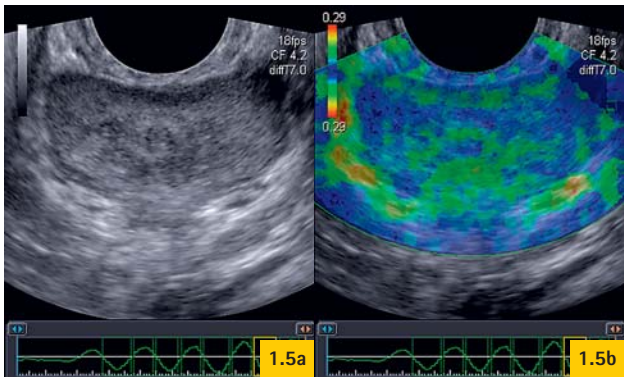


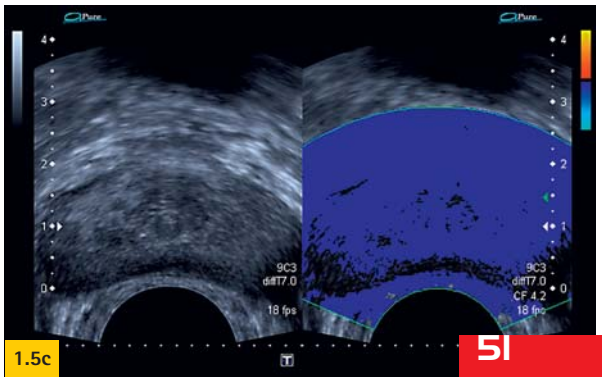




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Once the data is stored the strain image can be produced. The process takes about 10 seconds, and then the image can be viewed. Depending on the number of planes examined, obtaining the data for the images adds 1 to 2 minutes to the examination.

Although the patient feels the movement of the transducer during the "flicks" that compress the prostate, this is not painful or uncomfortable.

## Initial impressions

1. The system is easy to use. Data acquisition takes little time. The increased time required for the scan is quite acceptable. The split screen displays a greyscale image which makes it easy to align the elastography scan plane accurately to the plane which needs to be studied. The colour Doppler overlay allows an estimate of appropriate gain settings and indicates how much movement is being produced while flicking the transducer. Obviously abnormal areas are visible in real time on the colour Doppler image.
2. The technique is not uncomfortable or painful.
3. Post-processing and measurement of the images is easy, though best practices are not yet clear. The images appear to be reproducible over a range of different pressures when flicking the transducer and over a range of gain settings. This makes the procedure highly reproducible and relatively operator-independent.
4. The method does demonstrate prostate cancer but initial studies indicate that sensitivity is too low to use elastography as the sole examination technique.
5. Both tumours which were not visible on the grayscale images and tumours that, as confirmed later, were only visible on the grayscale images were detected.
6. Initial studies indicate that elastography imaging may well have a place in the detection of prostate cancer but further research as to its precise role is required.

## Case Reports

### Case 1: Normal study

A 32-year-old man with haematospermia was referred for transrectal ultrasound imaging of the prostate and seminal vesicles. The results showed no findings. The patient agreed to an elastography study of his prostate. The normal pattern is shown. In the figures the greyscale image and the elastography image are displayed alongside each other (a, b). The colour Doppler image used in real-time to aid acquisition of the elastography image is shown in fig. (c).

The colour scale depicts elasticity. Green is medium elasticity, red is higher elasticity, blue is less elasticity. The darker the blue, the less the elasticity. Tissues that do not react to pressure are black. The colour elastography image is overlaid onto the greyscale image. It is possible to vary the merged image from 100% greyscale to 100% elastography. Most of the images shown are 50% of each.

Fig. 1.1a and b show the mid-gland in the transverse plane. A continuous band of green (medium elasticity) is seen across the posterior gland. This does not correspond to the peripheral zone which is much wider in this young man. It may be simply because the tissue nearest the transducer moves more on flicking the transducer than the more distal tissues. The more posterior part of the gland is shown in medium blue with irregular, rather random areas of green. Rotating the transducer, so that the lateral horns are in the midline of the image, results in a green band along the horns. This is often not as clearly continuous as that in the posterior gland (Fig. 1.2, 1.3). The base of the gland (Fig. 1.5) shows a similar pattern as the mid-gland (Fig. 1.4). At the apex the green band is discontinuous or often absent.

### Case 2

A 58-year-old man with a serum PSA of 30.5. Digital rectal examination showed a firm left gland. Greyscale ultrasound (Fig. 2.1) showed a hypoechoic nodule in the left peripheral zone. Elastography showed a gap in the normal green band (Fig. 2.2) and on a slightly different plane a dark, stiff area (Fig. 2.3) that matched with the hypoechoic nodule. This corresponded to positive biopsies in this area, Gleason grade 7. In cases where greyscale match elastography results biopsies of the abnormal area might be all that is necessary. Fig. 2.4 shows the corresponding velocity gradient image.

### Case 3

A 62-year-old man with a serum PSA level of 3.9. Digital rectal examination showed an enlarged prostate with no palpable nodules. Greyscale ultrasound (Figs. 3.1a, 3.2a) showed no obvious focal nodules. Elastography showed loss of elasticity in the left peripheral zone laterally in the mid-gland



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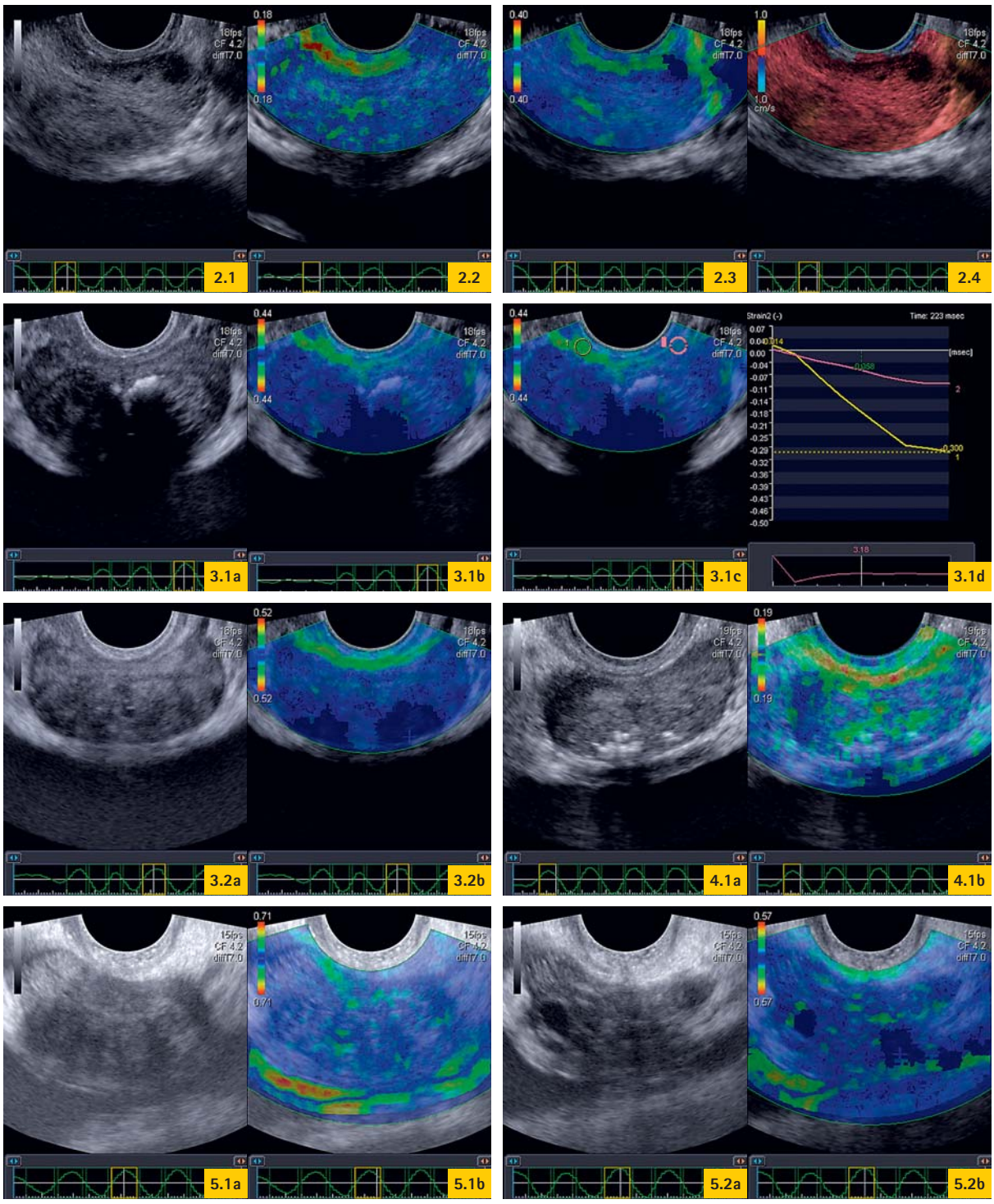


(Fig. 3.1a) but not in the base (Fig.3.2b). Biopsies revealed a Gleason 6 tumour in the area of decreased elastography. Figs. 3.1c and 3.1d show elasticity measurements of the abnormal area and the corresponding area on the normal side. The different graphs are obvious.

## Case 4

A 58-year-old man with a serum PSA level of 9.6. Digital rectal examination was computable with a T2A tumour on the right. Greyscale ultrasound (Fig. 4.1a) showed a large hypoechoic area on the right extending into the transitional zone. Elastography imaging (Fig. 4.1b) showed a matching area of decreased elasticity, shown as an area of darker blue. As the tumour was fairly anterior, the green posterior band is unaffected.

## Case 5

A 65-year-old man with increased serum PSA. Digital rectal examination showed a hard gland compatible with a T2A tumour. Greyscale imaging (Figs. 5.1a, 5.2a) showed an inhomogeneous gland but no focal nodules. Elastography (Figs. 5.1b, 5.2b) showed decreased elasticity throughout the gland with loss of most of the peripheral green band and



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areas of deep blue in the deeper parts of the gland. Biopsies showed extensive tumour with Gleason 9 tumour in all 10 cores taken.

## Two clinical workflows including elastography

The "easy" way to study the prostate with elastography imaging is to perform a transrectal scan of the prostate using greyscale ultrasound imaging together with Doppler studies if this is the standard practice of the department. In addition, elastography images of the prostate are acquired. After the examination the images are reviewed and measurements are obtained as appropriate. The prostate biopsies are obtained at a later date and are planned according to the elastography results. This has the advantage of allowing ample time to analyse the images. The examination, however, becomes a two-stage procedure which might be justified with patients with a rising serum PSA level and negative previous biopsies. With patients undergoing their first transrectal ultrasound and biopsy examination such a two-stage procedure is more difficult to justify. If future studies were to show that this two-stage approach provides a significant advantage, either higher positivity rate or the need for less biopsies, it would be acceptable.

An alternative approach is to analyse the elastography images immediately while the transducer remains in the patient and then to perform the biopsies with an appropriately modified pattern during the same procedure. This allows less time to analyse the images and multiple measurements are not possible. It is, however, possible to review the images in less than 10 minutes which means that together with the time needed to collect the data for the images the total time of the examination increases from about 15 to 30 minutes. During the analysis of the images the transducer could be removed from the rectum or could remain in place (insertion of the transducer is often the most painful part of the procedure).

## The possible role of elastography imaging

Sensitivity and specificity of elastography imaging need to be assessed further, both alone and when combined with the current standard technique of ultrasound-guided systematic biopsies. Therefore it is currently not possible to determine the role of elastography. Current experience, however, indicates certain possible conclusions.

Firstly, it is important to state what elastography will probably not achieve:

It seems unlikely that elastography imaging alone will replace the need for ultrasound-guided systematic biopsies. It is unlikely that the negative predictive value will prove sufficient to eliminate the need for biopsies in patients with a normal examination.

In cases where a lesion is detected, elastography will not eliminate the need for biopsy. It is unlikely that specificity will be sufficiently high to make an absolute diagnosis. Biopsy will still be needed to confirm the diagnosis and for Gleason grading.

Nevertheless, elastography might be used in several different ways:

1. There is a group of patients who have rising serum PSA levels and who have had two or more negative sets of biopsies. In these cases it is likely that a tumour has been missed, possibly because it is in an unusual position such as the anterior part of the gland. Current practice therefore is to perform "saturation" biopsies: about 20 biopsies are obtained including the anterior gland. This usually requires sedation or general anaesthetic. An alternative approach may be to look for the tumour using elastography. If found, it could be biopsied with far fewer cores under local anaesthesia.
2. If elastography imaging is added to grayscale imaging before biopsies are performed and a definite tumour is detected, then limited biopsies of the tumour may be all that is necessary. If no tumour is detected, systematic biopsies will still be necessary. Thus elastography could reduce the number of biopsies in a certain group of patients.
3. If elastography imaging is added to grayscale imaging before biopsies are performed and all patients have ultrasound-guided systematic biopsies by the current standard technique, plus targeted biopsies of elastography-detected lesions, this might increase positivity rates.
4. Elastography possibly assesses the size of tumours and the likelihood of extraprostatic spread. Since greyscale ultrasound is not suited for this task, MRI is often used but is not the ideal solution either. In addition, more aggressive tumours may have a different elastography pattern than less aggressive tumours – very valuable information when assessing treatment options. Both these possibilities need to be tested.

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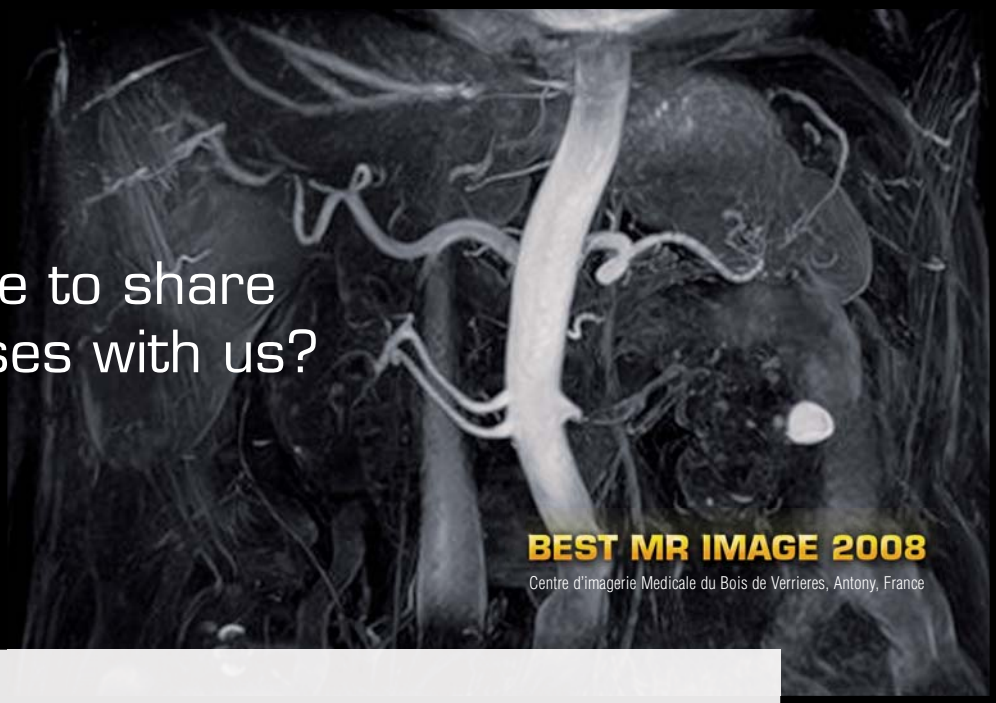


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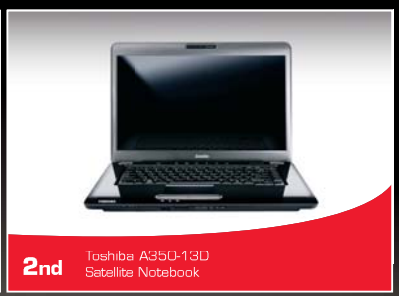
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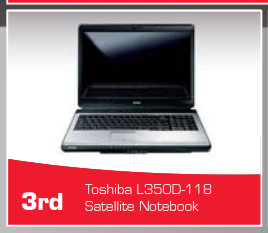
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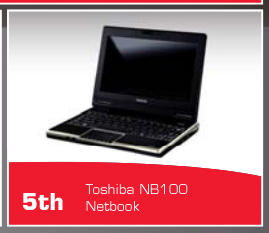
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