A renowned Hungarian cardiovascular center describes their experience with a new CT scanner dedicated solely to cardiac imaging

One of the most eminent cardiovascular centers in Eastern Europe, The Heart and Vascular Center, Semmelweis University, in Budapest Hungary is an interventional cardiology center with substantial diagnostic capabilities. Throughout its 100-year history, the center has enjoyed a reputation not only for highest quality clinical care, but also for keeping abreast of the latest technological advances in the cardiac imaging and interventional fields. Recently the center acquired a CardioGraphe CT scanner from GE Healthcare — the CardioGraphe is the first CT system on the market that is solely dedicated to cardiac imaging.

We wanted to find out more about the work of the Center in general and their experience of the CardioGraphe in particular so we spoke to Dr. Adam Jermendy, cardiac radiologist in the center.

Dr. Adam Jermendy is a cardiac radiologist at the Heart and Vascular Center, Semmelweis University, in Budapest Hungary
email: adam.jermendy@gmail.com

Q *Before we get on to the CardioGraphe, please give us a bit of background to your unit and the patients you see.*

Our institution essentially serves the capital Budapest and the surrounding counties, so covers a population of roughly three million people. From time to time we also see patients — usually more complicated cases — from further afield in the country. Since other centers in the region only started cardiac imaging program very recently, we have seen a large number of cases in the last couple of years. Most of the patients are referred to us for imaging from our own institute and from different outpatient clinics in Budapest, but smaller cardiac centers from the region also refer patients to us regularly.

Annually we scan around 3000 cardiac patients. On top of this we also provide general radiology services as well. We also take part in several multicenter imaging trials and our research group is involved in the evaluation of some of the very latest techniques such as on-site FFR, CT-perfusion or iterative reconstruction methods.

In our cath lab approximately 5000 invasive angiographies and 2700 coronary interventions are performed each year. Since non-invasive coronary assessment is a relatively new technique in Hungary, there are still a relatively high number of patients referred for invasive procedures who could have undergone CCTA. But with the growing number of cardiac-capable scanners around the country we expect this balance between invasive and non-invasive approaches to change in the near future. In our institute the demand for cardiac imaging is already very high.

Q *To deal with these patients, what imaging modalities and equipment do you have?*

In addition to the CardioGraphe, we have a Philips Brilliance iCT 256-slice scanner which we use for both general and cardiovascular imaging purposes. It's a fast scanner that gives excellent quality images with good temporal and spatial resolution and is also very reliable. It was one of the first scanners in Hungary that was capable of coronary imaging. Our MRI system is a recently acquired Siemens Magnetom Aera 1.5T which is mainly used for cardiac examinations although we perform general studies with it as well. We have a total of 24 radiologists and cardiologists working in the imaging department together with 15 operators. The medical staff

consists of mostly young and ambitious doctors who benefit from the environment created by the director of the clinic Prof. Bela Merkely, whose philosophy was to make possible not only the practice of healthcare at the highest level but also to encourage participation in advanced research and teaching programs.

Q *Since when have you had the GE CardioGraphe system ?*

We were one of the first two test sites for CardioGraphe in the world as part of a collaboration with Arineta, the company who originally developed the system and also with GE who now distribute it. Our CardioGraphe scanner was installed in December 2017. We participated in the R&D and evaluation of the scanner, giving continuous feedback to the engineers to help in the fine tuning of the system. The new scanner has a very small physical foot-print, which was a very important aspect for us, since our imaging department is already packed to bursting with equipment and is located in a relatively small building next to the main hospital facility, so we have little room for any expansion. In fact, the Cardiograph was installed in the place of one of our reading rooms. The installation itself went smoothly and once familiarization with the interface is achieved, there was no lengthy learning curve.

We tailor our acquisition settings individually for almost every patient, so easily customizable protocols are very important for us — the CardioGraphe completely meets our requirements in this regard.

Understandably enough in the first couple of months there were some technical teething troubles, such as relative instability of the system. These issues were rapidly dealt with by the very competent and responsive engineering support team — after a few software updates the stability was significantly improved. A recent update has introduced bolus tracking which makes the workflow much easier.

Q *When there is a reduction in physical size and cost of the system compared to "usual" high performance CT systems, it could be imagined that there will be some compromise on performance. Is this the case with the CardioGraphe?*

For the vast majority of the patients we deal with we don't see any such performance compromises, although the tube power is indeed a little lower compared to our other scanner, so obese patients and those with heavy calcification/stents can sometimes present challenges. The image quality was suboptimal in the beginning but the Arineta engineers successfully made a great effort to implement new filters and iterative reconstruction algorithms which improved the image quality. We are currently working on a new denoising algorithm that hopefully will be included in the next software update.

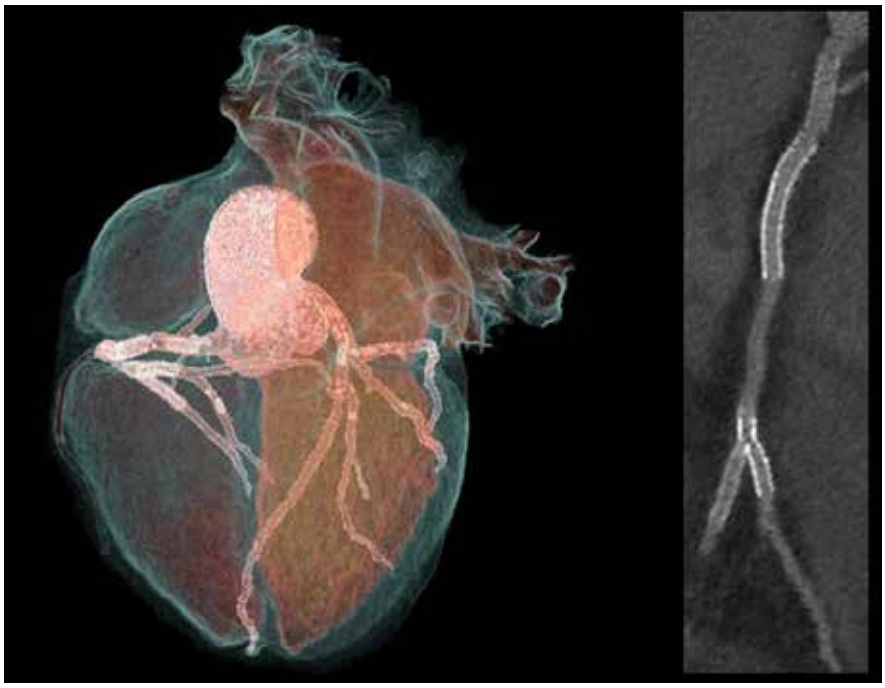
The CardioGraphe's rotation time of 0.24 sec beats that of our Philips scanner which is 0.27 sec. This apparently small difference is actually huge in terms of motion artefacts — we see much less motion in our scans. And the 14 cm coverage allows us to scan the whole heart in one beat, thus eliminating step artefacts. Obviously

The Cardiographe - an accessible CT scanner designed specifically for high performance cardiac imaging

Developed to enable affordable and easy access to high performance cardiac imaging, the CardioGraphe has a very small foot-print of only 15 m^2.

Principal Technical features include:

- Unique Stereo CT technology. Two overlapping x-ray beams rotate around the patient in parallel trajectories, achieving excellent image quality and wide z-axis coverage with no need for two detectors.
- Focused field-of-view (FOV).CardioGraphe's focused FOV of 250mm generates high-resolution images of the area of interest, while highly reducing radiation dose to peripheral anatomies compared to whole-body CT systems.
- Fast gantry rotation. The 0.24 second rotation speed with partial scan mode achieves excellent cardiac imaging, with a temporal resolution of 120 msec.
- Unique imaging chain hardware and Stereo CT reconstruction algorithm. Unique imaging chain and reconstruction technologies generate outstanding image quality.
- ASiR-CV. Integrated, advanced iterative reconstruction technology reduces noise and improves low-contrast detectability even at very low signal levels. This technology is designed to deliver reduced noise levels, improved low contrast detectability and may enable a reduction in dose for all clinical applications.
- Ultra-short gantry geometry. The ultra-short geometry makes efficient use of the x-ray sources.
- One-beat, high-definition, motion-free coronary images at any heart rate, with intelligent motion correction
- Comprehensive cardiac assessment for every patient – coronaries, structure & function
- Peripheral vascular imaging, from carotids to aorta, main pulmonary, renal and femoral arteries
- Whole organ acquisition for 4D imaging to visualize vascular flow, organ motion or kinetic properties
- SnapShot Freeze: algorithm to freeze coronary motion in high heart rate coronary CT exams to reduce motion blurring in vessels by up to a factor of six and improve effective temporal resolution accordingly.



CTA images of a 53 year old male patient with 51 bpm heart rate, BMI 31. Four stents are visible in the right coronary artery.

these are also features that are very useful when we scan patients with high heart rates or arrhythmia. In these cases there is also the possibility of extending the padding for systole and diastole, while maintaining a reasonable radiation dose. Despite this possibility, we still use our standard beta-blocker administration regime for the general patient population, in order to achieve as low heart rates as possible, so as to reduce the radiation dose to as low a level as possible. Generally, our average effective radiation dose with the CardioGraphe is 30-40% lower than that of our other scanner.

Q *How many patients have you now imaged using the CardioGraphe?*

So far we have performed around 1400 coronary CTA scans and a couple hundred other vascular cases such as TAVI, carotid, aorta scans. At the beginning we were cautious and only scanned selected cases, but when we were gained more confidence with the improved image quality and technical stability, we gradually increased the patient numbers. Nowadays, with the system up and running at its full capacity we can perform around 50-60 coronary cases per week. I think outpatient centers with this number of cases, say 50 patients a week would definitely benefit from a dedicated scanner like the CardioGraphe.

Q *Presumably one reason for the good temporal resolution is high gantry rotation speed, which in turn is facilitated from an engineering point of view by a narrow bore. Is the down-side of the narrow bore a difficulty in handling obese patients or those connected to cumbersome medical appliances?*

In practice, we've never had any patient who couldn't fit in the bore, and we have scanned many patients who had a BMI greater than 40. While technically it is always possible that a patient might be too large to fit in the bore, such obesity would mean that the image quality would inevitably be suboptimal, so the patient wouldn't benefit from CCTA scanning in the first place. Thus I feel that in practice the bore size is not a real issue. On the other hand, for example a patient on mechanical ventilation with multiple perfusor pumps could present some handling problems. However it should be remembered that the new scanner is mainly intended to serve outpatient centers rather than emergency departments.

" ... And the 14 cm coverage allows us to scan the whole heart in one beat, thus eliminating step artefacts..."

Q *What are the principal indications you use the CardioGraphe for? How do you decide which cases should be imaged on the CardioGraphe and which on high-end general use CT systems?*

The principal indications cover a broad spectrum of applications. We carry out examinations not only of cases of suspected coronary artery disease, but also stent and bypass graft follow-ups, heart transplant patients for allograft vasculopathy assessment, congenital heart disease patients and structural intervention planning. In addition, a large percentage of our scans are carried out for Electrophysiology (EP) planning, — the clinicians love the fact that we can rule out significant CAD and left atrial appendage thrombus in one setting, thus sometimes saving the patient from further testing.

Nowadays, we try to handle every cardiac case on the CardioGraphe. However, in cases where we need a large field of view, for example an additional lung scan, we choose the Philips scanner. CardioGraphe has a 25 cm FOV, which, while fine for the heart is not enough to encompass the full chest for most patients.

Q *The guidelines in some countries recommend cardiac CT as the first-line test for the evaluation of stable CAD in chest pain pathways. What's the situation in Hungary?*

For patients with suspected coronary artery disease, we try to comply with ESC guidelines, so more and more CCTAs are performed for the work-up of cases of stable CAD. This trend is especially true for major cardiac centers in large cities like our institute. However, Hungary as a whole is far from ideal in this respect, since our country lacks the sufficient number of scanners necessary to be able to routinely consider the CCTA modality as a real-life gatekeeper determining access to the cath lab. The overall trend towards this goal is positive, but we still need time for our infrastructure to reach the ideal level

of some western European countries. Nevertheless, recent studies and guidelines that confirmed the central role of CCTA should encourage health care executives to invest in the modality. Hopefully in the future we will be able to further improve patient management and outcomes with the extended use of cardiac imaging in Hungary.

Q *What about CT-derived FFR, which notoriously requires a high level of image quality for calculation of the parameter?*

Up till now we have only used CT-derived Fractional Flow Reserve (CT-FFR) in the context of clinical trials in which we have an ongoing collaboration with HeartFlow, and they regularly analyze our images. HeartFlow is the US-based company that is the only one to have had its advanced CT-FFR software approved by the FDA. In practice CCTA images are sent to HeartFlow who use their advanced algorithms to calculate and return the calculated CT-FFR values. These have been shown to correlate well with what has been up till now the standard method for calculating FFR, namely the wire-based pressure measurement system, which is of course invasive. The reliability of the CT-FFR calculated from CCTA depends on the quality of the images submitted — images that are not of good quality will be rejected without any calculations being attempted. According to Heart Flow, the quality of the images produced by the CardioGraphe are among the best in the field for FFR determination. In fact, they prefer them over our Philips iCT images.

" ... the quality of the images produced by the CardioGraphe are among the best in the field for FFR determination..."

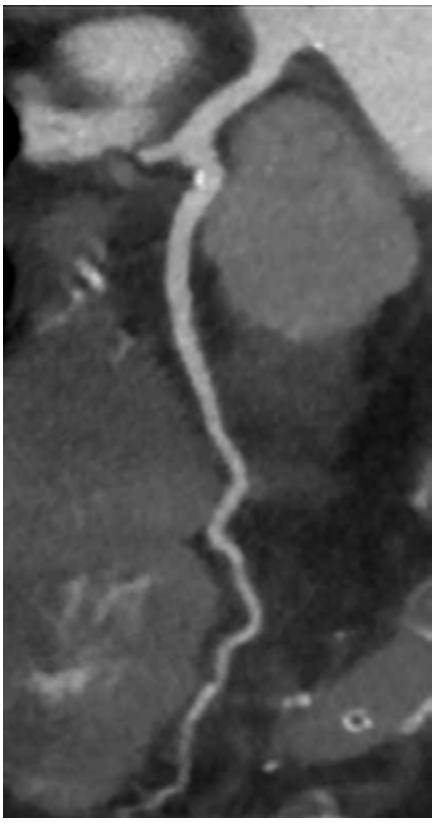
We are strong believers in the usefulness and validity of the CT-FFR approach. I hope that "on site" CT-FFR systems will soon be available to more centers in the future, since this would not only make the assessment of the severity of stenosis more convenient and accurate but would also make patient management much easier. However, image quality will always be the vital factor upon which the success of such "on-site" CT-FFR approaches will depend.

Q *So, all-in all, what's your opinion of the CardioGraphe?*

My opinion of CardioGraphe is absolutely positive. In particular, the constantly improving image quality, the large coverage and fast rotation time make it a robust clinical tool in cardiac imaging. Being a dedicated scanner there are only a limited types of scans you can perform with it so the lack of a general purpose ability could be considered a drawback. But it should be remembered that the system is not intended for any use other than cardiovascular imaging — if it is a general workhorse that is required there are plenty of other scanners on the market to choose from.

For a dedicated cardiovascular program this scanner is an excellent choice. In the future we hope to further improve image quality and an additional objective is to develop the possibility of performing CT-perfusion examinations with the CardioGraphe.

CT-FFR and CT-perfusion will definitely be the main focus as regards developments in CT over the next couple of years.



CTA images of a 67 year old female patient with 75 bpm heart rate, BMI 25.
Despite the relatively high heart rate no motion artefact is visible on the LAD artery.

Q *Finally an unrelated but topical question. What has been the effect of the COVID-19 pandemic on your institute?*

Because of "lock-down" constraints imposed by the current COVID-19 situation, many patients in most countries in Europe haven't been able to keep their appointments for follow-up radiology examinations. Fortunately in Hungary our lockdown came very early compared to some other European countries and the Hungarian people in general were very disciplined and took all the proposed preventative measures very seriously. This resulted in what could be described as only a mild pandemic with a generally modest number of cases that required hospitalization. Our health care system was challenged, but not overwhelmed. The big COVID-19 rush we had been expecting never came, and the biggest problem we now face is the number of patients whose care was put on hold — in our case many cancelled cardiac CT appointments. The Hungarian government and health authorities banned all non life-threatening care for a month and a half, and most of our cardiac program was included. Now that this ban has been lifted, we are faced with a significantly increased number of requests for scans. We have to take care that our imaging department doesn't get overwhelmed - but this is still a much better scenario than what it could have been if COVID-19 had hit us harder.