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Medical Solutions

Special Stroke Edition

Trends and Best Practices in Stroke Care

There are **17 million new stroke cases** each year, of which about **6 million** result in death.

70% of stroke cases occur in **low or middle income countries,** where the incidence is rapidly increasing.

1 in 4 stroke patients do not make it to the hospital in time.

With **each minute** saved in stroke management, an estimated **1.9 million neurons** of the patient can be salvaged.

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Bernd Hofmann,
Head of Neuroscience at
Siemens Healthcare GmbH

Dear Reader,

Latest state of the art imaging is supporting a significant improvement in diagnosis, precision of therapy, and outcome monitoring in stroke care. These advances significantly increase the patient's chances of survival and better quality of life after the incident, thus making disease management affordable by reducing the overall economic burden of long-term institutional care.

Whilst reducing door-to-needle time by optimizing processes and interfaces continues to play a key role in stroke management, a new and complementary approach is bringing the treatment closer to the patient: the mobile stroke unit. Beyond that, Stroke treatment is in the midst of a revolution, with positive clinical trials providing evidence that interventional therapy improves functional outcome.

However, stroke management still presents challenges, such as ensuring nationwide coverage by stroke units to provide high quality of care, selecting the right patients for interventional therapy and optimally integrating this step into the current workflow according to the hospital's infrastructure.

Siemens Healthcare supports neurology experts in reaping the benefits of new diagnostic and therapeutic possibilities while addressing key challenges. We offer imaging systems for different stroke workflow requirements and most suited to the customer's particular treatment strategy. Also, Siemens has first customer projects in place in the U.S. for the mobile stroke unit and supports emerging approaches for effective patient selection via perfusion imaging and vessel visualisation, providing insights into penumbra and collaterals. This is rounded up by clinical and process expertise. When it comes to building and operating Stroke Units, Siemens is a point of contact.

Working with neurological experts, we invest in advancing the diagnosis of stroke and in developing novel strategies for more individualized, more effective, and less invasive therapies.

In this issue, healthcare professionals from stroke care share their experiences, insights, and best practices. Much remains to be done, let's jointly work on solutions and push the boundaries of stroke care.

Bernd Hofmann
Head of Neuroscience at
Siemens Healthcare GmbH


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May the dance go on and on.
Siemens innovations help neurologists keep patients in step with the music.
As human beings, we aspire to long, happy and independent lives spent with the people we care about. For as long as the music plays, we want to be able to dance. Neurologic disorders such as stroke, brain tumors and Alzheimer's Disease can threaten this fundamental hope. Siemens provides advanced and scalable imaging, laboratory and IT systems that help clinicians provide clear and early diagnosis, precise and timely treatment, and efficient, well-coordinated management of neurologic disorders – all with the goal of helping patients achieve their highest potential independence. By helping to minimize or altogether avoid costly dependence on caregivers, Siemens innovations ultimately help providers deliver more sustainable neurologic care.
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Trends and Best Practices in Stroke Care

Highly Promising Improvements in Stroke Care

Four current stroke studies show the benefits of mechanical therapy in stroke – not only as regards increased quality of life for patients, but also in terms of cost efficiency. Furthermore, the time window for stroke treatment can be expanded with the aid of a combination of intravenous medications.

Text: **Sarah Schedl** and **Rebecca Murr**

The "door-to-needle-time" plays a vital role in saving brain cells.

Until 2014, studies did not show any benefits of mechanical therapy for cases of stroke. This was most likely due to a lack of experience at the centers participating in clinical trials, the use of old thrombectomy devices, and unfavorable patient selection. The MR Clean[1] (Multicenter Randomized Clinical trial of Endovascular treatment for Acute ischemic stroke in the Netherlands) study presented the first breakthrough and validated the use of mechanical thrombectomy for patients with acute ischemic stroke with large vessel occlusion in the anterior circulation.

A Broad Scientific Consensus

Since then, two further publications (Extend IA[2] and ESCAPE[3]) as well as the interim results from the SWIFT PRIME[4] study, have supported these positive results and were even stopped prematurely due to the positive interim analysis. In all three studies, death at 90 days was lower and chances of a good functional outcome almost doubled in patients that had received a combination of intravenous medication to dissolve the clot (IV tPA) and therapy via mechanical clot retrieval in comparison to patients who had only received medication.

Benefits for Both Patients and the Hospital

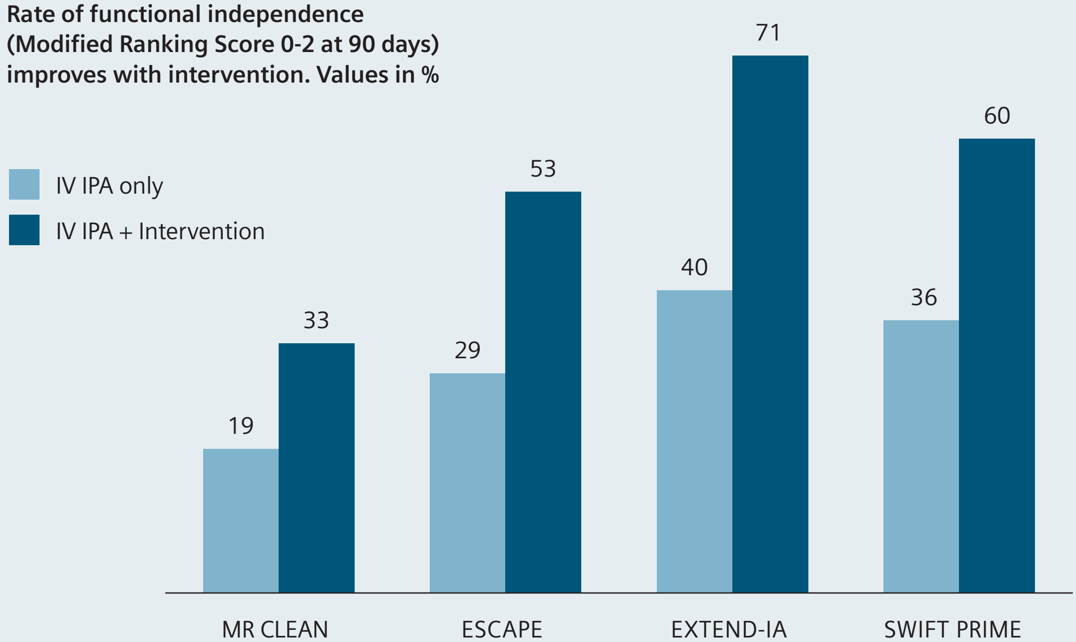
All four studies showed that the time window for stroke treatment could be expanded from 4.5 hours with IV tPA to 6 hours with mechanical therapy. The selection criteria in the ESCAPE study even included patients with an onset to treatment time of up to 12 hours after the start of the stroke.

In addition to the benefits as regards increased quality of life for the patients, mechanical therapy was also shown to be cost effective: the Royal Melbourne Hospital found that thrombectomy lowered overall medical costs by reducing the amount of days a patient spent in the hospital.[5] Bloomberg called this a "revolution under way in stroke care"[6].

The Role of Imaging

Imaging plays a key role in patient selection. In the studies, collaterals and the size of the penumbra proved to be key predictors for good therapy outcome and are visualized using either CT or MR angiography, or using perfusion CT or MR. Ultimately, the mechanical intervention requires precise device guidance through imaging in the angio suite. ■

[1] Berkhemer, Olvert A., et al: A randomized trial of intraarterial treatment for acute ischemic stroke, New England Journal of Medicine, 2015, 372
[2] Campbell, Bruce C. V. et al: Endovascular therapy for ischemic stroke with perfusion-imaging selection, New England Journal of Medicine, 2015, 372
[3] Goyal, Mayank et al.: Randomized assessment of rapid endovascular treatment in ischemic stroke, New England Journal of Medicine, 2015, 372
[4] Saver, JL et al: Solitaire™ with the intention for thrombectomy as primary endovascular treatment for acute ischemic stroke (SWIFT PRIME) trial: protocol for randomized, controlled, multicentre study comparing the Solitaire revascularization device with IV tPA with IV tPA alone in acute ischemic stroke, International Journal of Stroke, 2015, 10(3)
[5] http://www.bloomberg.com/news/articles/2015-03-19/new-hope-for-stroke-boosts-demand-for-device-to-nab-clots
[6] http://www.bloomberg.com/news/articles/2015-03-19/new-hope-for-stroke-boosts-demand-for-device-to-nab-clots



Rate of functional independence (Modified Ranking Score 0-2 at 90 days) improves with intervention. Values in %

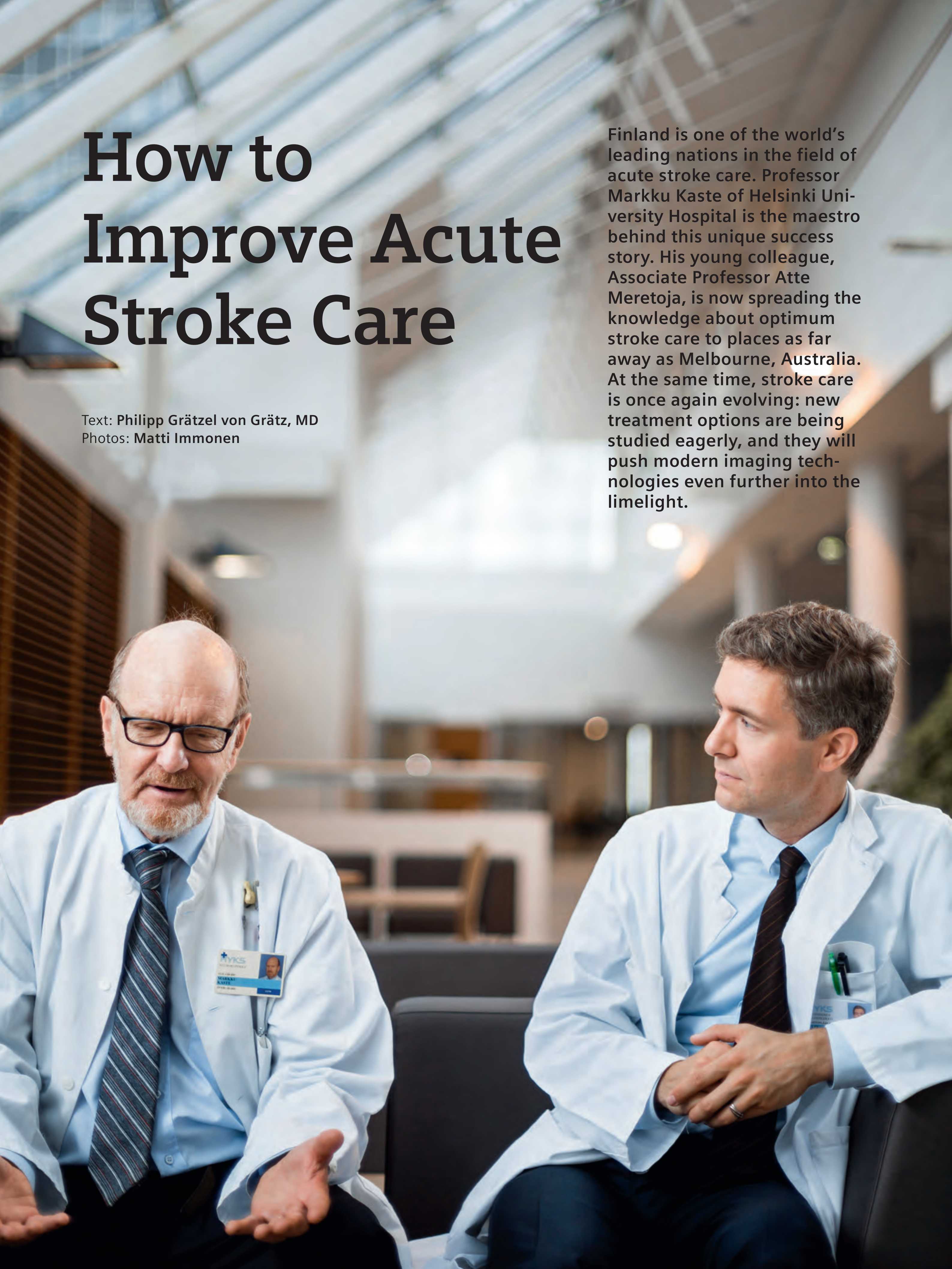
Sources:

(EXTEND-IA) Campbell, B. C. V., Mitchell, P.J et al. (2015). Endovascular therapy for ischemic stroke with perfusion-imaging selection. The New England Journal of Medicine 372

(MR CLEAN) Berkhemer, O. A., Fransen, P.S.S. et al (2015). A randomized trial of intraarterial treatment for acute ischemic stroke. The New England Journal of Medicine 372 http://www.ncbi.nlm.nih.gov/pubmed/25671798

(ESCAPE) Goyal, M., Demschuk, AM et al. (2015). Randomized assessment of rapid endovascular treatment of ischemic stroke. The New England Journal of Medicine 372, http://www.ncbi.nlm.nih.gov/pubmed/25882376

(SWIFT PRIME) Saver, J.L., Goyal, M. et al. (2015). Stent-retriever thrombectomy after intravenous t-PA v. t-PA alone in stroke. The New England Journal of Medicine 372.



How to Improve Acute Stroke Care

Text: **Philipp Grätzel von Grätz, MD**
Photos: **Matti Immonen**

Finland is one of the world's leading nations in the field of acute stroke care. Professor Markku Kaste of Helsinki University Hospital is the maestro behind this unique success story. His young colleague, Associate Professor Atte Meretoja, is now spreading the knowledge about optimum stroke care to places as far away as Melbourne, Australia. At the same time, stroke care is once again evolving: new treatment options are being studied eagerly, and they will push modern imaging technologies even further into the limelight.

How Times are Changing

When Markku Kaste began working in stroke care four decades ago, there was no computed tomography (CT) or magnetic resonance imaging. Stroke patients with intracerebral bleeding survived for three days on average. There was no causal therapy for patients with ischemic stroke. And specialized stroke units were a pipe dream.

Markku Kaste: There was nothing. Many neurologists didn't actually want to treat or see these patients, especially elderly patients, since there was so little that we could do for them. This has changed massively during the last decades. Thanks to modern imaging, we now know exactly what is going on in the brain. Several randomized controlled trials from the 1980s onwards made us aware that treating patients in specialized stroke units makes a huge difference: more patients now survive, and the likelihood of long-term disability has fallen considerably. Then intravenous thrombolysis came. We are getting quicker and quicker at administering it, and this means that we are able to rescue brain tissue that would otherwise be lost forever. All this has led to a steady increase in survival rates. There are more and more stroke survivors in Finland these days, and the number will increase further.

Atte Meretoja: We are in the fortunate position of having access to data on how exactly stroke care in Finland has evolved. The national Finnish PERFECT registry shows that, over the last ten years, we were able to reduce stroke mortality from 30 to 25 percent, and this trend is ongoing. Patients with intracerebral hemorrhages are also better off these days. They now survive on average for five years after the bleeding. Stroke incidence, by the way, is interesting to study as well. Finland has the most rapidly ageing population in Europe. In spite of this, the overall stroke incidence is pretty steady. In other words: for a given age group, the risk of suffering a stroke is actually falling. This is thanks to better risk factor control. The PERFECT data suggests that we have not only improved stroke care, but also stroke prevention.

Today's Stroke Care in Finland and Beyond

Improvements in stroke care in Finland are not restricted to the Helsinki area: The success story started there, but quickly spread throughout the country. The number of patients who are treated in specialized stroke centers has steadily increased in Tampere and Turku, in Oulu and Joensuu. Overall, 70 percent of all Finnish stroke patients ▸

Professor Markku Kaste (left) and Associate Professor Atte Meretoja (right) are active in spreading the word on optimum stroke care.

are now treated in stroke units. The remaining 30 percent are largely patients in the remote and sparsely populated northern parts of the country. But even then, at least indirect access to stroke specialists is available in most places. Helsinki University offers telestroke services to remote hospitals several hundred times a year, in addition to the 2,000 or so stroke patients treated on-site by the Helsinki neurologists. In fact, stroke patients in remote parts of Finland probably have a better chance of receiving the best care than patients in many other parts of Europe.

Markku Kaste: The European Stroke Initiative carried out a large study with more than 300,000 patients from all the major countries in Europe. It emerged that Europe-wide, only one out of seven stroke patients is admitted to a stroke unit. 42 percent are treated at hospitals with less than 50 stroke patients per year. Such a hospital will not and cannot have the necessary infrastructure for optimum stroke care.

Atte Meretoja: The most interesting figure in this context is the number of patients who get intravenous thrombolysis. In Helsinki, 16 percent of all ischemic stroke patients get intravenous thrombolysis. This is the population-based rate, and it is by far the highest in the world. The second-highest population-based rates are from Germany at 12 percent. In the US, the population-based intravenous thrombolysis rate in ischemic stroke is 4 percent. In Australia and in most European countries it is probably around 6 percent. Individual hospitals achieve higher rates, for example the Helsinki University Hospital at 31 percent of all ischemic stroke admissions.

When Speed is King

Using intravenous thrombolysis is one thing, but it is not enough simply to administer it. To be as effective as possible, it has to be used quickly. The neurologists in Helsinki have been working on an optimum protocol for intravenous thrombolysis administration for more than a decade. The target parameter was a reduction in what is called the door-to-needle-time. This is the time that passes from the moment the paramedics carry the patient through the entrance door of the hospital until the life-saving thrombolysis is finally administered. Door-to-needle-time is of the utmost importance in patients with ischemic stroke, not only for survival but also in terms of quality of life.

Markku Kaste: We have all these calculations that tell us how many neurons we can save by treating the patient quicker. But it is not only neurons. Being quick when a stroke patient comes to the hospital directly translates into quality of life for the patient. We have shown that saving 15 minutes in door-to-needle-time means on average one month more of high-quality life for the stroke patient.

Atte Meretoja: In Helsinki, we managed to reduce average door-to-needle-time to 18 minutes. This means that we are more than one hour quicker than, for example, our col-

"Improvements in stroke care at Helsinki University are cost-effective like buying a Mercedes and getting a BMW or two on top."

Professor Markku Kaste, Head of the Department of Neurology, Helsinki University Hospital

leagues in the US or indeed in many parts of Europe. This difference adds up to a plus of four months of disability-free life. That's a lot. It really makes a difference, not only for the statistics, but for every individual patient.

Step-by-Step Improvements

The massive reduction in door-to-needle-time at Helsinki University was a result of several measures that the neurologists introduced step by step over the period of a decade. Kaste, Meretoja, and their colleagues have recently published these steps in the form of a twelve-point priority list. One very important aspect on that list is a better involvement of the emergency medical services. The hospital is pre-notified that a stroke patient will arrive. This makes it possible to pre-order certain tests, to communicate with relatives, to obtain information on the individual medical history, and to take care of some of the usual admission bureaucracy in advance. Another important factor is the relocation of a CT-scanner right into the emergency department (ED).

Atte Meretoja: The relocation of the CT-scanner in 2004 was a crucial step. It didn't immediately lead to a reduction in door-to-needle-time, but it helped us to identify other bottlenecks that we could eliminate once the CT was available. Because we no longer had to wait for the CT, we realized how important it was to have proper pre-notification. Another example: we learned that for our stroke patients, it is not necessary to go through the ED cubicle. We transport stroke patients directly into the CT room. We do a brief neurological examination and some point of care lab tests and perform the CT examination immediately afterwards. The lab results are available as soon as the CT is done. These refinements of the admission processes save us an awful lot of time.

Markku Kaste: Another important aspect is that we have stroke specialists available at the emergency department all the time. We have 40 neurologists in total in our department. This makes it possible to offer a 24/7-service. The interesting thing is that the improvement in stroke care at Helsinki University is absolutely cost-effective. We carried out a monetary analysis for the year 2007, which revealed that we paid 11.3 million Euros for 2,000 stroke patients who were treated in our hospital plus 3.2 million Euros for the neurological emergency room with its 6000 admissions. The successful treatments with stroke unit care and thrombolysis saved us 14.4 million Euros in costs for chronic care. This means that the neurogical ER is actually cost neutral, and the hospital does not only get better stroke care, but also better care for other neurological emergencies like acute seizures. It's like buying a Mercedes and getting a BMW or two on top.

Helsinki University Hospital treats around 2,000 stroke patients on-site and offers telestroke services to remote hospitals several hundred times a year.

A Blueprint for Other Countries

Finland is only one country. So can the Finnish success story be transplanted to other territories? Atte Meretoja has recently proven that it can be. He left for a fellowship to Australia's University of Melbourne for 18 months to test the applicability of the Helsinki protocol in a totally different healthcare setting. The results were impressive. ▸

Management Summary

According to the experience of Professor Kaste of Helsinki University Hospital, acute stroke care can be optimized substantially by reorganizing processes in the ED. Due to improved communication between emergency service and hospital and CT imaging made available right in the ED, Helsinki University Hospital was able to get door-to-needle-time down to as little as 20 minutes. This will substantially increase the likelihood of good patient outcome and reduce the risk of permanent disability after stroke. Arming the ED with neurological expertise will also benefit patients with other neurological emergencies, for example seizures. In the future, the integration of neuroradiological angiography suites into the acute care setting might make stroke care even more of an interdisciplinary endeavor.

Atte Meretoja: Within a year, the Helsinki result could be duplicated. Measures of process improvement similar to the ones mentioned above drove door-to-needle-time down from 45 to 21 minutes. What was not possible was to copy the 24/7-service, since the neurological department at the Royal Melbourne Hospital was far smaller than the one in Helsinki. But still, a lot was achieved through relatively simple measures.

Joining Forces

Industry, too, can help to spread the message of better stroke care through process optimization. The Act on Stroke initiative that was launched by Siemens Healthcare Consulting in 2010 specifically aims to improve processes in stroke treatment. Based on a systematic model encompassing care guidelines and clinical expertise, it allows the level of maturity of complex clinical processes to be rated for an individual hospital.

Markku Kaste: We are all in one boat that is heading in the same direction. We will achieve the best results if we join forces. Industry has considerable experience in how to effectively distribute information. It is far better at it than we are. Why not help to distribute printed guidelines, for example? Why not support training projects of the European Stroke Organization? We have to tell our colleagues all over the world in as many face-to-face meetings as possible about how optimum stroke care can and should be organized. This is our duty.

Not Yet Over the Finish Line

What optimum stroke care looks like in the year 2013 can be seen at Helsinki University. But stroke care as it is today is certainly not carved in stone. Stroke therapy could well

Modern stroke care would be inconceivable without rapid brain imaging. At Helsinki University Hospital, reallocating a CT to the emergency department enables thrombolytic therapy to be administered to stroke patients in only 20 minutes.

More Insights Into the Finnish Approach

Markku Kaste and Atte Meretoja explain how they improved workflows in the stroke unit of Helsinki University Hospital and how that affected the outcome for the patient.

To watch the video, scan the QR code using the reader app on your smartphone or enter the URL into your browser.

www.siemens.com/acute-stroke-care

change considerably in the years to come: intra-arterial clot retrieval devices that can be used to manually extract blood clots and open obstructed cerebral arteries are already being tested in numerous clinical studies. The challenge is to select stroke patients who benefit from these therapies as effectively and – again – as quickly as possible. This will necessitate modern imaging technologies that go well beyond the plain CT imaging that is still, in many places, the standard of care in CT diagnostics.

Atte Meretoja: Intra-arterial therapies are heavily researched in the stroke community worldwide. At our institution, we perform around 50 to 100 recanalizations with intra-arterial devices per year. The global stroke community hasn't nailed the selection criteria for these interventions yet, but I am pretty sure that we will get there over the next couple of years. Imaging will definitely play a role here. At the moment, we supplement the plain CT scan with a CT angiography and a CT perfusion scan in patients who might benefit from interventions in addition to intravenous thrombolysis. It could well be that, in the future, we will use the CT to directly image collaterals or to measure the lengths or even the composition of a clot.

How Times Will Still Be Changing

Parameters like clot length or the degree of collateralization might help to allocate patients to the best therapies. But they have to be tested rigorously in clinical trials, and indeed they are already being tested.

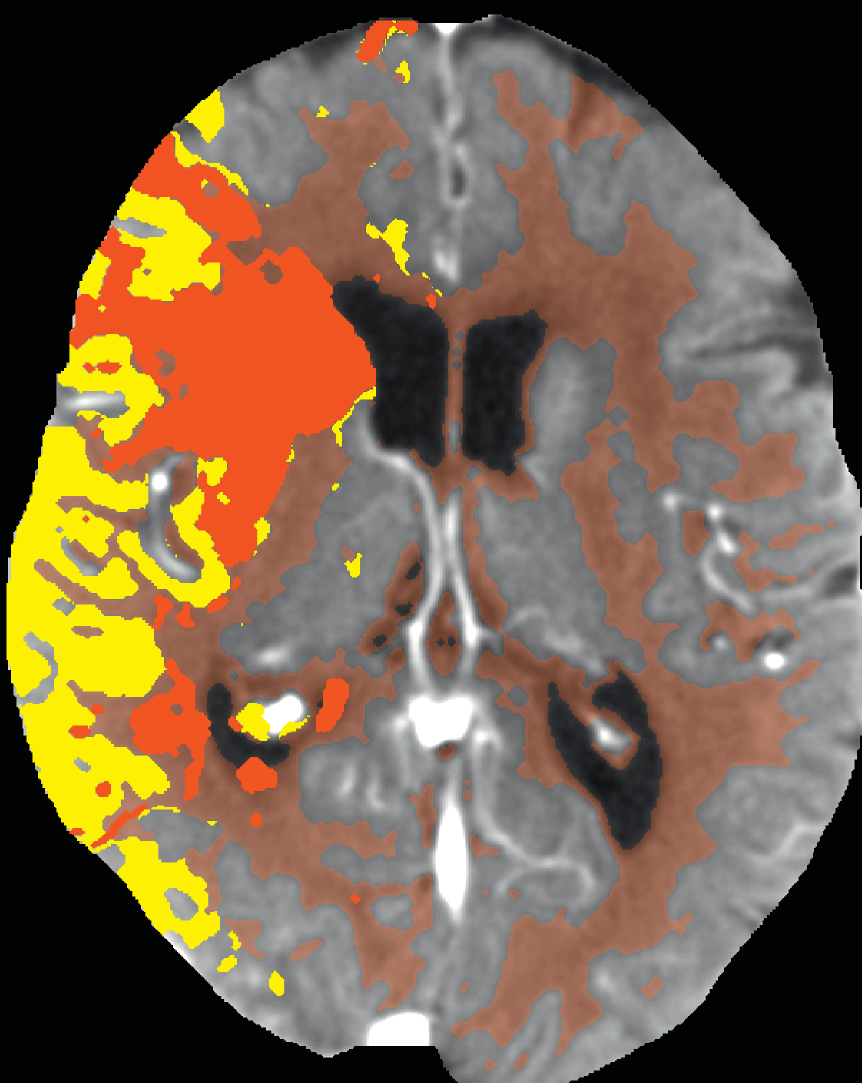
Markku Kaste: These are exciting times in stroke care. We will see a lot of interesting results from ongoing trials in the years to come. One thing that won't change is that emergency imaging will remain the cornerstone of stroke care. The other thing that will always be true is that good stroke care is about teamwork. Today, paramedics and hospital staff have to cooperate closely to achieve the shortest possible door-to-needle times. And in future, neurologists, interventional neuroradiologists, and neurosurgeons might have to cooperate far more closely than they do today to provide optimum interdisciplinary treatment for our stroke patients. Maybe we will have a common emergency room for diagnosis and treatment of acute stroke patients one day, similar to the cath labs of cardiologists. Who knows? ■

Philipp Grätzel von Grätz is a medical doctor turned freelance writer and book author based in Berlin, Germany. His focus is on biomedicine, medical technology, health IT, and health policy.

A Stroke Diagnosis in Less Than 10 Minutes

"Our aim is to restore the blood supply to affected tissue in stroke patients as soon as possible," says neuroradiologist Peter Schramm, MD, of Göttingen's University Hospital.

Text: **Oliver Klaffke**



Easily see core infarct (red) and penumbra (yellow) with the tissue at risk model.
Courtesy of University Hospital Goettingen, Goettingen, Germany

"Our aim is to restore the blood supply to affected tissue in stroke patients as soon as possible," says neuroradiologist PD Peter Schramm, MD, of Göttingen's University Hospital. This is essential if neurological damage is to be kept to a minimum, as up to two million brain cells can be lost every minute following a stroke: "time is brain".

Three key diagnostic questions are need to be answered in acute stroke: "How large are the areas of core infarct and tissue that could potentially be saved (penumbra) with further treatment in the brain tissue? Is the stroke caused by bleeding or a clot? And what is the size and location of the clot?" All three questions can be addressed with CT.

The new perfusion imaging application *syngo*.CT Neuro Perfusion is now available on the thin client-server platform *syngo*.via. "Treatment without precise knowledge of core infarct size and penumbra may do more harm than benefit," says Schramm. "Therefore, diagnostic imaging tools are required to see the size of the core infarct and penumbra. These need to be able to cover the whole brain, safely, accurately and fast."

"The *syngo*.CT Neuro Perfusion includes a Tissue at Risk model that is based on the mismatch between blood volume and blood flow," Schramm says. However, users can also select a custom mismatch, based on user-defined perfusion metrics. Schramm is investigating the Siemens' unique metric, Time To Drain (TTD), to look for signs of early ischemia. Important, but often overlooked are differences in the hemodynamics of gray vs. white matter: therefore the penumbra analysis can be restricted not only to the affected hemisphere. On top of that it can per selection be limited to the brain gray matter. For whole brain perfusion imaging, the Adaptive 4D Spiral technology moves the table of the CT smoothly back and forth, providing coverage beyond the width of the detector.

The acute therapy varies according to what caused the stroke: thrombolytics need to be administered when a clot is responsible; however, they are contraindicated when bleeding is the cause. A native head scan will answer the question "is it bleeding or is it a clot" quickly. Excellent image quality is required here as the subtle nuances indicative of the early signs of ischemic stroke can be difficult to see. "I routinely use Neuro Best-Contrast," says Schramm.

If the result discovers a clot as the reason for the stroke, treatment can include the administration of thrombolytic drugs to dissolve the clot on the one hand and, increasingly, interventional techniques for clot retrieval. "With modern neurointerventional techniques, such as catheters and clot retrieval devices, there's practically no proximal intracranial artery we can't open up," says Schramm. To do this, it is vital to see exactly where the vessel is obliterated. Generally, one can determine the location of the clot by scrolling through axial CT Angiography (CTA) source images. However, estimating the size of the clot is somewhat cumbersome and often not possible, since the images are taken at a single point in time. This is where *syngo*.CT Dynamic Angio comes into play. Dynamic CTA appears to be a solution to this limitation. Movies of blood flow, from arterial to venous phases can be created and temporal Maximum Intensity Projections (tMIP) especially seem to better characterize the clot size due to retrograde collateral filling.

"With my SOMATOM Definition AS+ and the CT Neuro Engine, I am able to identify core and penumbra, exclude bleeding and determine the size and location of the clot," says Schramm. "Routinely, patients are ready for stroke intervention in less than 10 minutes. This gives me confidence in better selecting patients that may benefit from interventional stroke treatment," concludes Schramm. ■

"We need a reliable stroke diagnosis within 10 minutes."

PD Peter Schramm, MD, Neuroradiologist, University Hospital Goettingen, Germany

Oliver Klaffke is a science and business writer, who lives in Switzerland and France. Publications for which he has written previously include the New Scientist and Nature, among others.

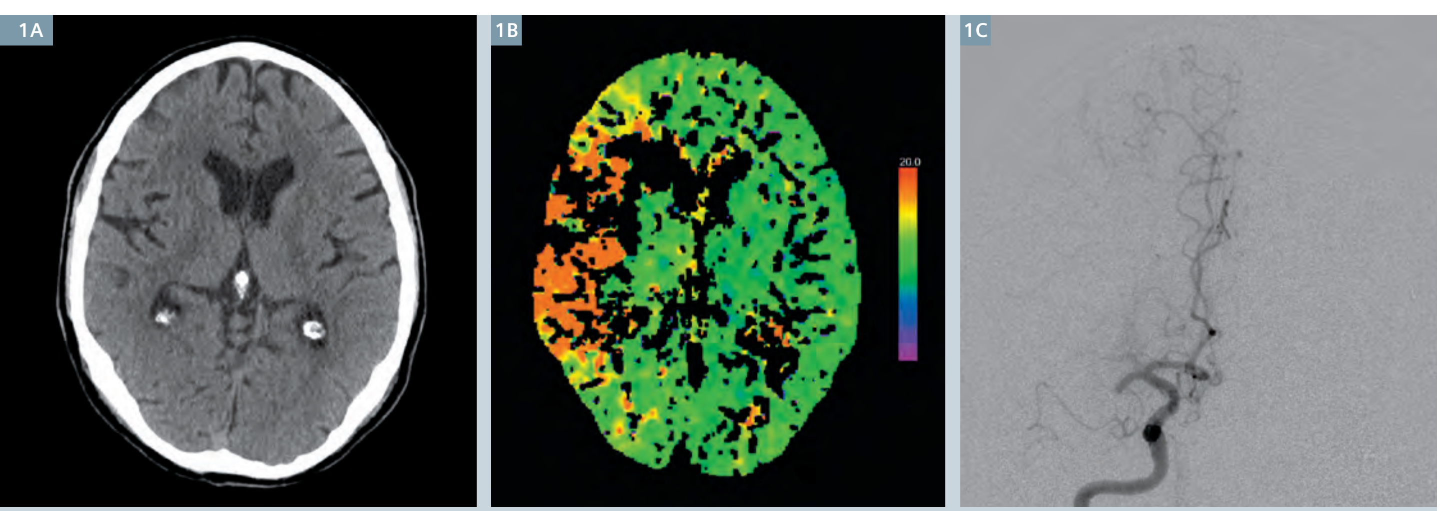
Mechanical Thrombectomy – Faster than Ever

When caring for a patient with acute ischemic stroke, Professor Martin Bendszus and his team are racing against the clock. Using a combination of a CT scanner and mobile C-arm they cut the transfer time between stroke diagnosis and mechanical thrombectomy. The patient is diagnosed and treated in the same room on the same table, without transfer. Already in the first three patients, picture-to-puncture time was as little as 35 minutes.

Text: **Hildegard Kaulen, PhD** Photos: **Carsten Buell**

The world of stroke has changed. For a long time, the only proven effective treatment for acute ischemic stroke was intravenously administered thrombolysis with recombinant tissue-type plasminogen activator (r-tPA). Now, mechanical thrombectomy has advanced to become an important option. Clinical studies with intriguing names such as MR CLEAN, ESCAPE, EXTEND-IA, SWIFT-PRIME, and REVASCAT have demonstrated that interventional clot retrieval improves the outcome for certain stroke patients. The evidence was so convincing that the American Heart Association/American Stroke Association updated its guidelines back in June 2015 – giving the strongest recommendation possible for patients who meet certain criteria: class 1, level of evidence A.

Around 100 mechanical thrombectomies were performed in 2014 in Heidelberg – this number was reached within the first six months in 2015. "Since the studies were published, we have received many more referrals from hospitals in the area and are doubling our numbers this year," says Professor Martin Bendszus, MD, from Heidelberg University Hospital in Germany. Bendszus is Head of Neuroradiology. His department is a key component in the Heidelberg University Hospital stroke center, one of the leading stroke centers in Germany treating hundreds of stroke patients per year. With strict eligibility criteria, Bendszus estimates that around 15 percent of the 270,000 strokes per year in Germany could potentially be considered candidates



1A–C A 74-year-old male patient was admitted due to an acute stroke. An initial native CT (Fig. 1A) image showed no signs of an early stroke. The perfusion image (Fig. 1B) revealed a delayed time-to-peak (TTP) in the right hemisphere. Angiographic imaging (Fig. 1C) demonstrated a right-sided M1 occlusion.
Courtesy of Heidelberg University Hospital, Germany

“Since the studies showed that mechanical thrombectomy is a safe and effective treatment for acute ischemic strokes, we no longer ask why we should perform one, but rather why we shouldn’t.”

Professor Martin Bendszus, MD,
Head of Neuroradiology,
Heidelberg University Hospital, Germany

for mechanical thrombectomy. With broader criteria, he estimates this number may increase to 20 percent.

In the case of a stroke, the decisive factor – in addition to the patient’s age and the National Institutes of Health Stroke Scale (NIHSS) – is the time it takes to restore perfusion. “In recent trials it was shown that if the blocked artery can be recanalized 20 minutes faster, this increases the chances of a better clinical outcome in the range of 10-15%,” says Bendszus. Unfortunately, in most hospitals critical time is lost while patients are transferred between emergency room, diagnostic imaging, and interventional suite, as well as with negotiations between parties preceding each transfer. In Heidelberg, the CT and biplane angiography systems are located in adjacent rooms, yet it still takes fifteen to twenty minutes to move a patient. If the rooms are located further apart, as is the case in a number of hospitals, the move takes much longer. During the time the brain is not perfused approximately two million brain cells die every minute. This is why, when planning his second thrombectomy suite, Bendszus looked for a solution that avoided the need to move the patient, and with a better picture-to-puncture time. He wanted the diagnostic imaging and the mechanical opening of the artery to take place on one table and in one room. In a combined system, the technical personnel can begin preparing for the intervention directly after the patient has been scanned – the best way to minimize picture-to-puncture time.

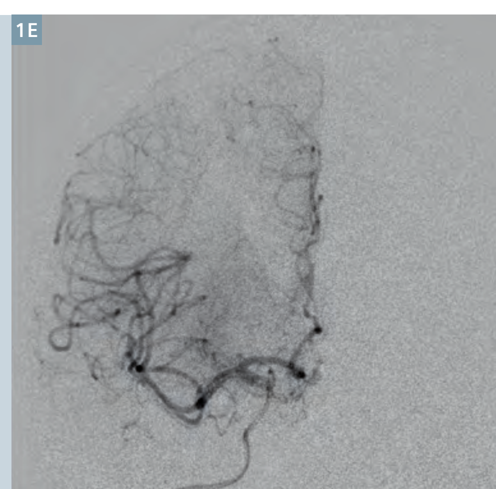
Bendszus had three requirements for the new intervention suite: It had to be a solution that would not restrict normal CT operation. His department performs over 15,000 CT examinations per year, so the room had to be used for normal daily routine, too. In addition, everyone who would be performing a mechanical thrombectomy ▸

1D

The patient was treated with mechanical thrombectomy. The picture-to-puncture time was 38 min; the groin to the first recanalization time was 24 min; and the groin to final thrombolysis on the cerebral infarction scale (TICI) 3 was 50 min.

The patient’s NIHSS had improved from 16 (initial) to 2 (after 24 hrs.) and then to 0 (at discharge, day 4).

1E



1D, E A native CT image acquired after treatment (Fig. 1D) showed a small infarct (hypodense area) in the right basal ganglia. An angiographic image (Fig. 1E) demonstrated a complete recanalization of the right cerebral middle artery.
Courtesy of Heidelberg University Hospital, Germany

in the room should be immediately familiar with the system, with similarities to a standard angio system, and the system should provide sufficient image quality to perform the procedure safely. Finally, it was important for Bendszus to be able to switch from CT operation to the interventional procedure very quickly in the case of an acute indication for a thrombectomy. "We had a Formula One pit-stop approach in mind," he says, "where everything is ready and available for use within a few minutes."

CT and mobile C-arm in a single room

How were his requirements met? The new suite is equipped with a SOMATOM Definition AS for diagnostic imaging. In the adjacent room, a mobile Cios Alpha C-arm with flat detector technology is available for the mechanical thrombectomy. It takes five minutes to set up. The CT table is placed at a distance of 95 cm from the gantry so that the C-arm can slot into this space during the intervention. The standard CT table is made of carbon and, using a commercially available extension, is longer than usual so that it is also suitable for the thrombectomy. The CT table, CT scanner, and C-arm can be controlled using remote controls mounted at the tableside, or on a trolley, similar to a standard angio system. The two monitors are mounted on the ceiling. A radiation protection wall was also installed. "What makes this CT and C-arm system so special is its simplicity," explains Bendszus. "We're using a 64-slice CT system and a mobile C-arm without any expensive reconstruction costs, and achieve a high level of flexibility and accessibility."

In a feasibility study supported by Siemens, Bendszus and his colleagues have shown that diagnosing and treating stroke patients with the combined system is feasible. "The combination is equally suited for this procedure, compared to conventional angiography systems," says Johannes Pfaff, MD, the physician in charge of the study. "The excellent performance and large field-of-view of the Cios Alpha deliver an image quality that is more than adequate to safely maneuver the instruments. The system has all the essential elements for angiography," Pfaff explains. The feasibility study was published in May 2015 in the *Journal of Neurointerventional Surgery* (doi:10.1136/neurintsurg-2015-011744).

Average picture-to-puncture time of 35 minutes

Pfaff and Bendszus treated three patients as part of the feasibility study: An 84-year-old with an occlusion in the M1 segment of the left-middle cerebral artery; a 51-year-old with an occlusion in the basilar artery following a wake-up stroke; and an 83-year-old with an occlusion in the M2 segment of the left-middle cerebral artery. "The average time between the diagnostic scan and puncture of the femoral artery was 35 minutes," says

The new suite at Heidelberg University Hospital is equipped with a SOMATOM Definition AS for diagnostic imaging. In the adjacent room, a mobile Cios Alpha C-arm with flat detector technology is available for the mechanical thrombectomy and it takes five minutes to set up.

"The time needed from high-quality CT stroke imaging to groin puncture could become as low as 28 min. None of us has ever been this fast. And we are pushing even further."

Johannes Pfaff, MD,
Heidelberg University Hospital, Germany

Pfaff. "The time needed from high-quality CT stroke imaging to groin puncture could become as low as 28 min. None of us has ever been this fast. And we are pushing even further." Time was saved crucially by keeping the patient in one place. If a patient has to be moved from the CT room into the neighboring angio suite, the picture-to-puncture time was 57 minutes in previous studies, and the picture-to-recanalization time was 250 minutes. In Heidelberg, all emergencies are now treated in the new suite. That is, unless two emergencies have to be treated concurrently. "We now have the problem that we're so fast that the logistics have to be adjusted," says Bendszus. "The anesthetist should theoretically already be in the room for the diagnostic CT scan." Following the feasibility study, a larger study will now be conducted with fifty patients in order to confirm the incredibly impressive times. "We already included 34 patients," says Pfaff. "We hope to publish the results in 2016."

Decision-making based on the infarct core and penumbra

Who is eligible for mechanical thrombectomy? "We decide on the basis of the infarct core and the size of penumbra, not only on the basis of the time elapsed after symptom onset," says Bendszus. The infarct core is the amount of irreversibly damaged tissue. The penumbra is malperfused tissue that may still be saved through fast recanalization. Core and penumbra are both measured using CT perfusion imaging. In studies that have been published, mechanical thrombectomy was performed within twelve hours following the onset of symptoms. "If the infarct core is small and the penumbra is large, the time elapsed is less relevant," says Bendszus. "Since the studies showed that mechanical thrombectomy is a safe and effective treatment for acute ischemic strokes, without an increased risk of complication, we no longer ask why we should perform one, but rather why we shouldn't." Bendszus also considers a wider range of indications. The published studies report on the treatment of patients with occlusions in the internal carotid artery and the proximal middle cerebral artery. In Heidelberg, also more distally located thrombi are removed using stent retrievers. The primary risk is that part of the thrombus is lost during its retrieval, causing a new embolization in another place. "We can perform a diagnostic CT scan at any point during the intervention, which allows us to react immediately to any complications," says Pfaff. "This is a significant safety factor."

Need for structured training

Which hospitals should offer mechanical thrombectomy? "Maximum care hospitals with a Department of Neurology have to offer this procedure," says Bendszus. "However, proper training is essential for the intervention. You have to understand the approach and learn how to probe the vessels. You also have to understand the diagnostic images." This is why Bendszus calls for structured training, emphasizing that it is now up to professional medical associations to ensure that high-quality care is available across Germany in the near future.

Bendszus also envisages a new trauma room concept. Following the diagnostic CT scan, various vascular interventions can be performed on the same table. The effectiveness of the treatment can then be checked as required during the intervention using CT imaging. "The amazing thing is that it's so easy to implement without needing any additional construction work," says Bendszus. "Here, the technology is driving forward the clinical applications." ■

Hildegard Kaulen, PhD, is a molecular biologist. After stints at the Rockefeller University in New York and the Harvard Medical School in Boston, she moved to the field of freelance science journalism in the mid-1990's and contributes to numerous reputable daily newspapers and scientific journals.

A phantom head helps simulate brain tissue for testing new methods and tools in neuroradiology.

The Right Mind at the Right Time

As a stroke expert, Dr. Charles Strother has treated countless patients. As a researcher, however, he helps develop methods and technologies that may enable thousands of his colleagues to treat their patients faster and more effectively in the future.

Text: **Jürgen Schönstein** Photos: **Steffen Thalemann**

No one knows the field of neuroradiology better than Dr. Charles Strother, Professor Emeritus of the University of Wisconsin School of Medicine and Public Health in Madison, Wisconsin. When Dr. Strother is asked about the history of this relatively young discipline, he can think of a dozen names – such as Per Amundsen from Norway, a pioneer of minimally invasive catheter technology, or Guido Guglielmi, the inventor of the eponymous Guglielmi Detachable Coil (GDC), still a standard tool for neuroradiologists, Dr. Thomas Hans Newton, former Professor of Radiology and Head of Neuroradiology at the University of California in San Francisco, Russian neurologist Fedor Serbinenko, and Dr. Strother's co-workers Charles Mistretta and Guang-Hong Chen. But there's one name he never mentions: his own. The 73-year-old neuroradiologist tells us, without any sign of false modesty, that he is only "along for the ride." This, however, is one of the most ridiculous understatements imaginable. There is a reason why Dr. Strother was the recipient of the ASNR Foundation Outstanding Contributions in Research Award at this year's annual meeting of the American Society of Neuroradiology, and why he is one of the most frequently quoted neuroradiology authors in the world.

Helping Doctors Help Patients

Dr. Strother, who has treated countless patients in a clinical career spanning more than 45 years, is one of the world's leading stroke experts. He has also researched and developed numerous successful treatment methods and technologies. In short, Dr. Strother has not just helped patients directly, but during the last four and a half decades has played a decisive role in helping his colleagues treat their patients more effectively.

At the beginning of his career, however, even Dr. Strother himself could not have predicted that he would become one of the top experts in his field. "My father enjoyed mocking me that I had managed to 'squeeze' the workload of eight semesters into ▸

Dr. Strother is currently working with Siemens on further developing biplane 3D options in angiography for stroke patients.

> *"Outstanding medical physicists are the key to every success I've ever had."*
>
> **Dr. Charles Strother**, Professor Emeritus of the University of Wisconsin School of Medicine and Public Health, Madison, Wisconsin, USA

five years," he explains. Academic work was simply not his thing back then. "I was anything but an outstanding student. I was more interested in sports, especially football and baseball." And more than once, he even had to transfer schools after falling hopelessly behind in his studies.

Medical school would not have even occurred to Dr. Strother if he hadn't – by pure chance – taken a work-study job in a hospital in Fort Worth, Texas. The job was washing laboratory glassware, and as menial as the task was, it awakened his interest in medicine. At the age of 22, in 1963, he enrolled at the University of Texas in Galveston. Four years later, he graduated with high honors and began his clinical training in internal medicine at the University of Wisconsin in Madison.

In another typical, yet decisive, coincidence, Dr. Strother was again in the right place at the right time to meet his future wife, Elizabeth, whose brother happened to be a neurosurgery resident at Stanford University in California. After completing his military service, during which he served as a physician in the Special Forces in Panama, Dr. Strother moved to Stanford to begin his residency as a neurologist. During his residency training, he also had a rotation in radiology, which he felt was a rather boring department. "We couldn't really treat anything in the brain," Dr. Strother says. "There was diagnostic angiography, but no therapeutic interventions."

Learning to Be Minimally Invasive

It was then, however, that he met Norwegian visiting professor Per Amundsen, who had developed a minimally invasive catheter method as an alternative to the then-commonplace practice of injecting contrast medium directly into the artery. "I saw these small incisions in the groin, saw that the patient was conscious – and I thought to myself: 'This is exciting. This could change everything.'" He decided to become an interventional neuroradiologist.

The idea that doctors can use radiology methods not just for diagnoses, but also for minimally invasive procedures was put into practice during Dr. Strother's

The next big challenge for Dr. Strother and his colleagues: Trying to intervene before aneurysms develop.

fellowship at the University of California in San Francisco. “We had several patients with recurrent nosebleeds,” he explains. “My colleagues and I got the idea to use a catheter to block the bleeding vessels with small particles.”

With far-reaching success: the journal article about this embolization, published by Dr. Strother and the former chairman of Radiology at UCSF, Hans Newton, in 1976, triggered a chain reaction. It inspired Russian neurosurgeon Fedor Serbinenko, for example, to develop a detachable balloon catheter that allows doctors to treat vascular malfunctions, such as carotid cavernous fistulas, which until then had been virtually untreatable.

“It was a terrible situation, and the surgical procedure was gruesome – only a few patients survived it,” Dr. Strother says. “But the balloon catheter worked great.” It was the first neuroradiological instrument that had a significant clinical benefit and was far superior to every other method.

In general, Dr. Strother seems to have been present whenever there was a new breakthrough in neuroradiology. In the early 1990s, Italian neurosurgeon Dr. Guido Guglielmi experimented with electroembolization methods at the University of California in Los Angeles (UCLA) and, in the process, (accidentally) developed a detachable platinum coil that is used to occlude brain aneurysms. Dr. Strother came into contact with this technology very early on through a friend from his studies at Stanford whose company had started devel ▸

About Dr. Charles Strother

Born in McKinney, Texas in 1941, Dr. Charles Strother is an Emeritus Professor at the University of Wisconsin School of Medicine and Public Health in Madison. Since 2012, he has devoted himself to medical and technical research at the Clinical Science Center in Madison, with financial support from Siemens Healthcare and the National Institutes of Health. He began his medical career at the University of Texas in Galveston; he discovered neurology (especially neuroradiology, which has been decisively shaped by him) during his time as a resident at Stanford University in California, where he recognized the possibilities of endovascular catheter technology.
Dr. Strother has spent the majority of his career at the University Hospital in Madison, with brief stays in Paris, Oslo, and Baylor University in Houston, Texas. He was elected to a one-year term as president of the American Society of Neuroradiology in 2003, which honored him with the ASNR Foundation Outstanding Contributions in Research Award in 2014. As stroke expert, he is the author of four books and more than 150 scientific publications, including some of the most frequently cited publications in this discipline.
When he is not researching new technologies, such as 4D angiography, Dr. Strother enjoys traveling to exotic destinations with his wife, Elizabeth, or jogging around the lakes of Madison to stay in shape.

Management Summary

Challenge:
Development of practical treatment methods and technologies in interventional neuroradiology.

Solution:
Combining more or less random discoveries and ideas in daily hospital routine with inventive spirit and technical expertise.

Result:
The development of, among other things, the life-saving detachable balloon catheter or the Guglielmi Detachable Coil (GDC) into a clinically usable product.

oping the coil into a clinically usable product. Today, it is referred to as the Guglielmi Detachable Coil – or GDC Coil – and Dr. Strother, who had since returned to the University of Wisconsin, was involved. "We put a lot of work into our lab," he says. "The University of Wisconsin was the second clinic in the world (after University of California, Los Angeles) to use these coils to treat aneurysms."

The Key to Success: Collaboration

Dr. Strother was hired by the University of Wisconsin in 1976 to help build a growing section of neuroradiology. It was the close proximity to the colleagues in medical physics here that, in his own opinion, helped him the most: "These outstanding medical physicists are the key to every success I've ever had," he insists. His colleague Charles "Chuck" Mistretta, for example, developed Digital Subtraction Angiography (DSA) here.

Imaging is crucial to everything that specialists in this field do. As Dr. Strother explains: "Anything we can see, we can generally also repair. Imaging is a fundamental component that makes all of this possible." There is no comparison to the film-based methods he had to work with at the beginning of his career. Every minute counts, especially with ischemic strokes: "As we say, 'time is brain' – or rather 'time is neurons.' It is estimated that for every minute of ischemia, you lose about two million neurons." The less damage there is, the more quality of life remains for the patient, which also translates into dramatically fewer follow-up and long-term care costs – an important argument especially in light of the current healthcare cost reform in the United States.

That being said, however, rushed treatment can sometimes be more harmful than helpful. "First of all, in a patient with an acute ischemic stroke, we have to determine what damage has already occurred and then decide if intervention will only make the situation worse," Dr. Strother says. He is currently working with Siemens on further developing biplane 3D options in angiography that would allow doctors to bring stroke patients directly

into the angio suite and do all the diagnostic imaging there, which would spare them the long stays in CT or MR, as well as transfers to and from those modalities. "We are talking about the angio suite as the stroke unit of the future, and that's catching on, from Germany to China."

Looking at Time

One essential element for this is the flat detector, which can image soft tissue in CT quality and visualize high-contrast blood vessels in better spatial resolution than with a conventional CT. Dr. Strother, however, who has concentrated fully on research in this area since his retirement to emeritus status in 2011, is no longer satisfied with these high-resolution 3D images. "I always realized that the 3D modeling with the contrast medium flowing through the vessel should also include temporal information in the dataset," he explains. "But I didn't know how to get it."

He went to Dr. Mistretta, whose office is next to his and who had already developed 3D DSA, and asked him: "Chuck, there has to be a way." And the more Mistretta insisted it was impossible, the more Dr. Strother urged him to try. "At some point he gave in – probably, just to finally get rid of me," Dr. Strother says. "Three days later, he had found a solution." 4D DSA is currently being developed in cooperation with Siemens, and it is hoped that this technology will translate into fewer X-rays and therefore less radiation exposure for patients, but also into lower costs.

This story demonstrates that Dr. Strother is not just "along for the ride" when it comes to research, as he himself claims. If anything, he is a scout with a refined sense of what the future holds. And what does his sense tell him about his own future as a researcher? "I hope it will tell me when I should stop – before other people do." ■

"We Try the Best We Can All the Time"

Neuroradiology was decisively shaped by Dr. Strother. In this film, he looks back at his impressive career.

To watch the video, scan the QR code using the reader app on your smartphone or enter the URL into your browser.

www.siemens.com/charles-strother

Jürgen Schönstein, who has a graduate degree in Geography (Diplom-Geograph), has been a journalist since 1985. He has worked for *DIE WELT*, *Springer Foreign News Service* (New York Correspondent) and *FOCUS* (U.S. Correspondent from 2001 to 2010), to name just a few. He has been the editor-in-chief of the German science portal ScienceBlogs.de since the beginning of 2011 and teaches academic writing at the Massachusetts Institute of Technology. Jürgen Schönstein is also a freelance writer for the German economic journal *BILANZ* and lives in Cambridge, Massachusetts.

Alternative Treatment Decision in Stroke Patient with Carotid Stenosis Supported by *syngo* DynaCT

Courtesy of Marios Psychogios, MD

Department of Diagnostic and Interventional Neuroradiology, University of Goettingen, Germany

Marios Psychogios, MD

Patient History

A 64-year-old male patient presented 4.5 hours after symptom onset with right-sided paresis.

Diagnosis

The NCCT (non-contrast computed tomography) at admission showed a left dense sign of the middle cerebral artery (MCA) and initial ischemic signs of the left insular ribbon and lentiform nucleus (NCCT-ASPECTS 8). A multidetector computed tomography angiogram confirmed the MCA thrombosis and depicted an additional proximal thrombosis of the left internal carotid artery, due to a high-grade stenosis.

Based on these findings, the following original treatment plan was as proposed:

1. Dilate the carotid artery stenosis using percutaneous transluminal angioplasty (PTA) in order to access the occluded MCA.
2. Remove the occlusion/clot using a stent retriever (thrombectomy).
3. Stent the carotid artery.

Treatment

Low-dose DSA images (Figs. 1–2) show the carotid artery before and after PTA, performed to access the clotted MCA. Following successful clot removal by stent retriever and before stenting the carotid artery, a non-contrast *syngo* DynaCT acquisition was acquired to assess the current situation. The *syngo* DynaCT scan (Fig. 3) revealed hyperattenuated lesions of the basal ganglia due to contrast extravasation and/or hemorrhage. This finding is associated with hemorrhagic infarct transformation[1] and prompted a change to the original treatment plan:

It was decided not to stent the carotid artery, nor administer aspirin and clopidogrel in the acute setting. Instead, physicians performed ultrasound follow-up imaging of the carotid artery and stenting was performed seven days after endovascular therapy.

In this case, the high-quality *syngo* DynaCT scan supported safer treatment of the patient, enabling physicians to tailor their treatment to the current situation and, therefore, improve the patient's outcome.

Protocol

20s DCT Head

[1] Hyperattenuated intracerebral lesions after mechanical recanalization in acute stroke. AJNR Am J Neuroradiol. 2014 Feb;35(2):345-51

Contact

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1 Low-dose DSA image shows stenosis of left carotid artery.

2 Low-dose DSA image shows the left carotid artery following PTA.

3 Non-contrast *syngo* DynaCT after thrombectomy shows hyperattenuated lesions of the basal ganglia due to contrast extravasation and/or hemorrhage (MPR, 5 mm).

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