National Research Foundation

# SCiENCE MaTTERS

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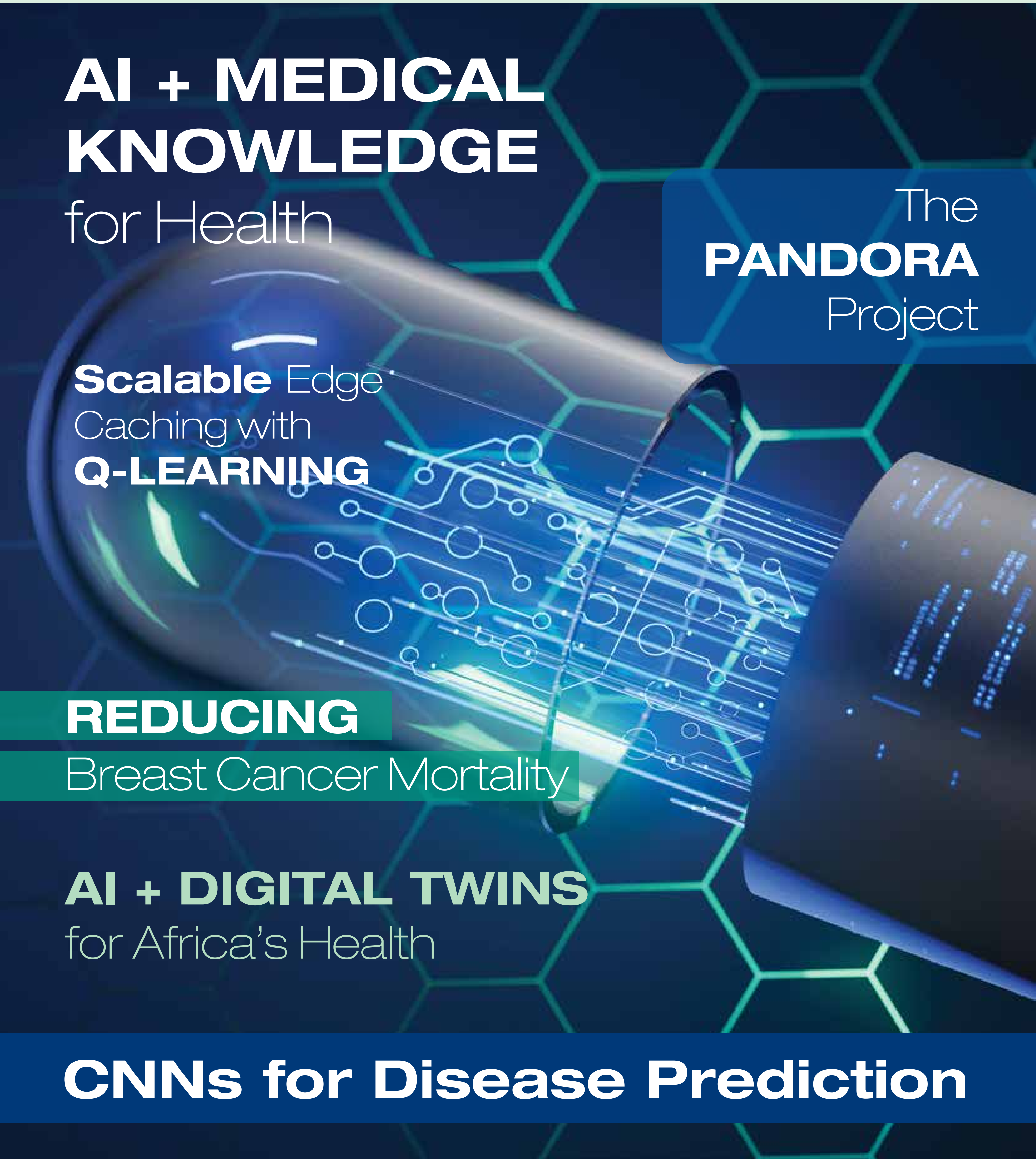

## AI + MEDICAL KNOWLEDGE for Health

## The PANDORA Project

## Scalable Edge Caching with Q-LEARNING

## REDUCING Breast Cancer Mortality

## AI + DIGITAL TWINS for Africa's Health

## CNNs for Disease Prediction


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# SCiENCE MaTTERS

Welcome to the second issue of the seventh volume of the National Research Foundation (NRF) Science Matters magazine. This magazine aims to bring to you a collection of insightful research articles that address some of today's most pressing challenges in health, technology, and science.

In this issue, we focus on research that uses science and technology to solve real problems in health and beyond. The articles look at how AI can help doctors predict diseases, monitor patients, and improve public health in Africa. We also cover new cancer studies that explore smarter treatments to save more lives, while other research looks at how radiotherapy can be made shorter and easier for patients. At NRF-iThemba LABS, scientists are studying powerful cosmic rays to better understand the Universe and improve nuclear medicine. There is also research on faster, smarter digital networks to handle the world's growing data needs.

The NRF would like to thank all the researchers who generously shared their research for this issue of Science Matters, and therefore allowing us to showcase the unique perspective of South African scientists and how they make a difference every day.

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# A STUDY OF
# The Generalisability of CNNs for Disease Prediction

**From detecting brain tumours to spotting the early signs of lung and skin cancer, convolutional neural networks (CNN) have proven themselves as powerful allies in modern medicine.**

These deep learning systems can scan through thousands of images and recognise patterns that even the most experienced human eyes might miss. But in most research, CNNs are trained and tested on a single disease at a time.

Could they be more versatile, learning to predict multiple diseases without needing to start from scratch each time?

This was the question driving a study by Thashil Naidoo and Professor Nelishia Pillay, the DSTI-NRF Research Chair in Artificial Intelligence for Sustainable Development at the University of Pretoria. Their research explored whether CNNs could generalise, perform well across several different diseases, and whether a training technique called the Incremental Neural Network Approach (INNA) could boost performance while reducing the cost of computation.

The team focused on three medical challenges where image-based diagnosis is critical:

- Brain tumour diagnosis
- Lung cancer detection
- Skin cancer diagnosis

They tested two popular CNN architectures, AlexNet and ResNet34, under two conditions. First, they trained and evaluated each network individually for each disease. Then, they tested the same networks across all three diseases combined to see if a single model could adapt to different diagnostic tasks.

The researchers also tested the INNA method. INNA begins by estimating how difficult each image is to classify, splitting the dataset into easy, medium, and hard examples. The network is trained in stages, starting with easy cases, then moving on to more challenging ones. This gradual learning approach aims to improve efficiency and accuracy.

When tested separately on each disease, the results were clear:

- AlexNet came out on top for brain tumour diagnosis.
- ResNet34 delivered the best results for both lung cancer detection and skin cancer diagnosis.

The study showed that, when tested across all three diseases at once, ResNet34 proved to be the most generalisable, outperforming AlexNet and the INNA method.

The INNA approach did not outperform the two CNNs in overall accuracy, but it showed two important advantages. First, it required less computational power, a potential benefit for resource-limited healthcare systems. Second, in the specific case of lung cancer detection, INNA outperformed existing state-of-the-art methods, showing that the approach can deliver significant gains in certain contexts.

The findings suggest that while no single CNN is the best for every disease, models like ResNet34 show strong potential for multi-disease prediction, reducing the need to train separate systems from scratch. Approaches like INNA, which lower computing costs while maintaining competitive accuracy, could make AI-driven diagnosis more accessible, especially in regions where resources are limited.

As AI in healthcare continues to grow, research such as this brings us closer to versatile, efficient diagnostic tools that can adapt to multiple challenges, supporting doctors and improving patient outcomes worldwide. SM

***Full research paper: Contact NRF SA Chair, Professor Nelishia Pillay, University of Pretoria, Pretoria, South Africa – nelishia.pillay@up.ac.za https://ieeexplore.ieee.org/document/10605338***

The network is trained in stages, starting with easy cases, then moving on to more challenging ones. This gradual learning approach aims to improve efficiency and accuracy.

# BLENDING MEDICAL KNOWLEDGE AND AI for Disease Risk Prediction and Continuous Health Monitoring


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**From predicting heart rhythm disorders to real-time hospital-wide early warning systems.**

Modern healthcare produces enormous amounts of information every day. Hospitals store patient histories, laboratory results, diagnoses, and treatment records in Electronic Health Records (EHRs). While Artificial Intelligence (AI) and machine learning have significantly improved the accuracy of disease prediction, they often function as "black boxes", providing results without explaining how those results were reached.

For doctors and healthcare providers, accuracy alone is not enough. They need AI systems that can explain their reasoning, adapt to new circumstances, handle uncertainty and integrate with diverse health information systems. This is especially important in hospital settings where patient safety depends on quick, reliable and well-understood decisions.

A research study funded by the NRF has worked on a hybrid AI approach that addresses these challenges. The solution combines two powerful knowledge-based methods:

- Knowledge graphs (KGs) – Structured networks that represent medical knowledge, linking diseases, symptoms, risk factors and treatments.
- Bayesian networks (BNs) – Models that capture cause-and-effect relationships and can reason with incomplete or uncertain information.

> ... not only predict risk but also explain the reasoning behind those predictions...

By integrating KGs and BNs, the researchers aim to create AI systems that are accurate, interpretable, adaptable and capable of continuous health monitoring.

The research first focused on a single case study: predicting the risk of atrial fibrillation (AF), a common and potentially serious heart rhythm disorder. AF can lead to stroke, heart failure and other complications if not detected early. The researchers used anonymised EHR data from the MIMIC-IV data set which contained demographic details, diagnoses, laboratory test results, and medication histories. Their process involved:

1. **Knowledge graph construction** – Medical literature and expert clinical input were used to create a KG representing established relationships between AF, its risk factors, symptoms, and related conditions.
2. **Bayesian network integration** – Relevant portions of the KG were transformed into a BN, enabling probabilistic reasoning about patient risk even if some data was missing.
3. **Parameter learning** – Real-world patient data was used to refine the probabilities in the BN, tailoring the model to the specific hospital population.
4. **Evaluation** – The hybrid model's performance was compared with standard data-driven AI models to assess both accuracy and interpretability.

The results were significant—the hybrid model matched the predictive accuracy of purely data-driven models. The system could trace predictions back to specific medical knowledge in the KG which gave clinicians a clear explanation of why a patient was considered at risk. The BN allowed the system to produce reliable predictions even when some patient information was missing. Combining general medical knowledge with local hospital data improved relevance and accuracy for the hospital's unique patient population.

This approach showed that integrating KGs and BNs can produce AI tools that doctors can trust because they not only predict risk but also explain the reasoning behind those predictions.

After proving the concept with AF, the research team expanded its work into a broader semantic interoperability architecture for continuous and explainable health risk monitoring across multiple diseases.

The goal was to integrate health data from various hospital departments and external sources into one intelligent system that could assess risks in real time, issue early warnings, and explain its decisions to clinicians.

The proposed architecture operates in three main layers:

1. **Data layer** – Patient data from hospital systems, laboratory information systems and other sources is standardised using recognised medical ontologies (structured vocabularies) so it can be merged into a unified framework. External medical knowledge bases are also linked into this structure.
2. **Analysis layer** – The combined dataset is processed by the KG–BN hybrid model, enabling the system to assess multiple disease risks simultaneously, handle uncertainty, and update predictions continuously as new data arrives.
3. **Decision layer** – The system generates alerts, recommendations, and natural-language explanations that link each prediction back to relevant medical knowledge. This ensures transparency and trust in clinical decision-making.

Testing in a simulated hospital environment demonstrated that the system could monitor patients' health risks continuously rather than at single points in time; detect early signs of deterioration before symptoms became severe; and provide clear, understandable explanations for every alert or prediction.

Across both studies, the hybrid KG–BN approach delivered several advantages:

- High accuracy – Matching or exceeding the performance of standard AI models.
- Interpretability – Predictions are linked to established medical knowledge, making them easier for clinicians to trust and act on.
- Adaptability – The model can incorporate both global medical research and local patient data, ensuring relevance to specific healthcare contexts.
- Robustness – The ability to handle incomplete or uncertain data is critical in real-world hospital environments where information may not always be complete.
- Scalability – The framework can be adapted to monitor multiple diseases simultaneously, enabling hospital-wide early warning systems.

By starting with AF risk prediction and scaling up to continuous multi-disease monitoring, the research demonstrates a clear path from targeted clinical decision support to a fully integrated hospital intelligence system.

In the short term, this technology could help doctors make faster and better-informed decisions for individual patients. In the longer term, it could form the foundation for intelligent hospital networks in South Africa and beyond, where AI systems work alongside healthcare professionals to improve outcomes, optimise resources, and ensure patient safety. SM

***Full research studies: Integrating Knowledge Graphs and Bayesian Networks: A hybrid approach for explainable disease risk prediction*** ***https://arxiv.org/abs/2506.13920***
***A Semantic Architecture for Continuous Health Monitoring, Risk Prediction, and Proactive Decision Making*** ***https://link.springer.com/chapter/10.1007/978-3-031-63592-2_20***

# RESEARCH NUGGETS

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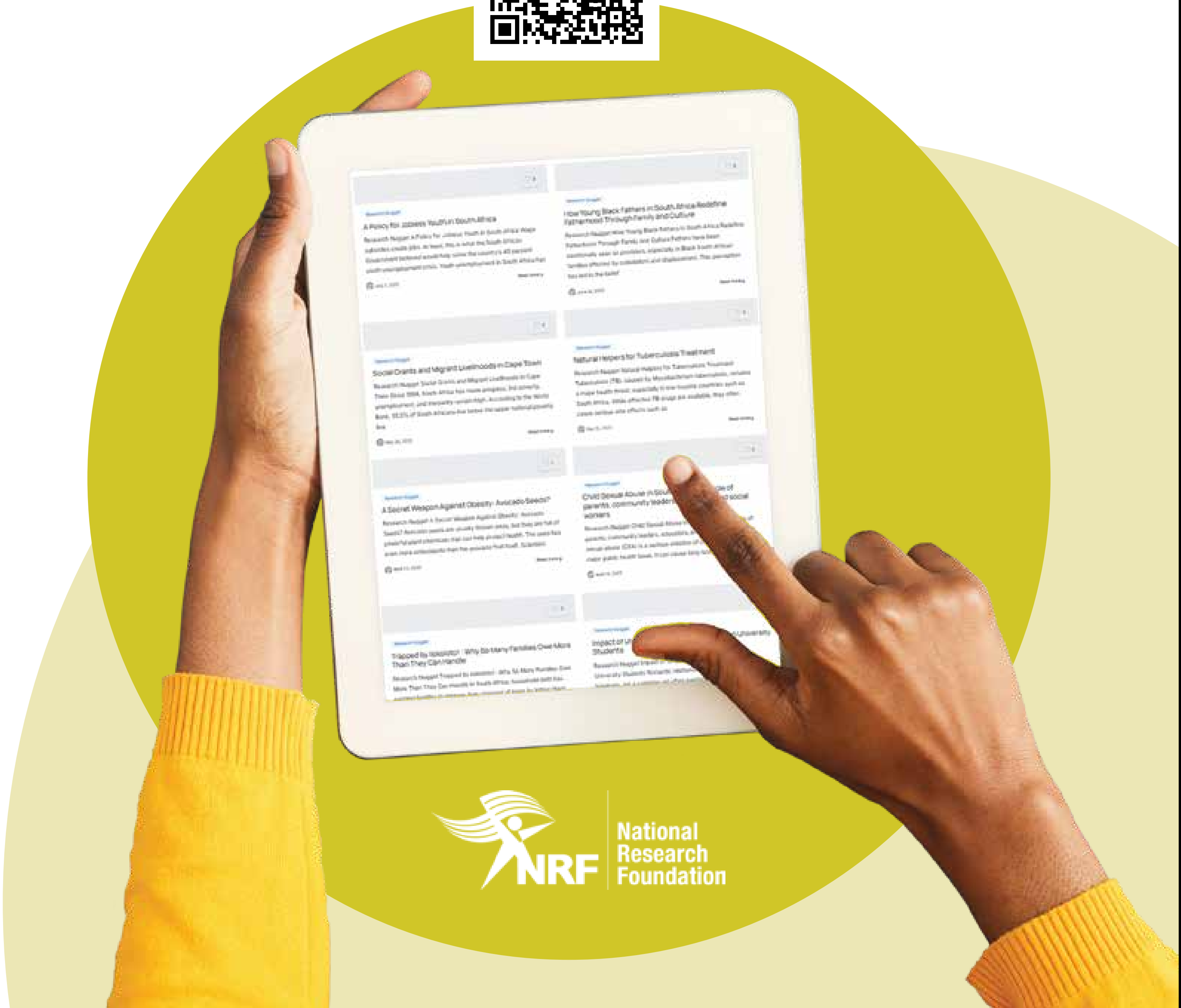

# Tracing the Universe's Most Powerful Particles at NRF-iThemba LABS: **THE PANDORA PROJECT**

**Beyond our atmosphere, space is filled with tiny, fast-moving particles known as ultra-high-energy cosmic rays (UHECRs). They reach Earth with astonishing power, far greater than anything we can create in laboratories.**

At NRF-iThemba LABS in Cape Town, scientists are part of an international research effort called the Photo-Absorption of Nuclei and Decay Observation for Reactions in Astrophysics (PANDORA) Project, which seeks to understand what happens to these particles as they travel across the universe.

The PANDORA project focuses on how lighter elements such as carbon, oxygen, and magnesium behave when struck by very high-energy light. These reactions, known as photonuclear reactions, are crucial for explaining how UHECRs lose energy in space. By measuring this energy loss, scientists can trace how far the particles have travelled and learn more about their origin.

UHECRs, whether protons or atomic nuclei, carry more than ten million times the energy of particles accelerated by the Large Hadron Collider (LHC), the most powerful machine on Earth. As they move through the cosmos, they encounter the faint glow of the Cosmic Microwave Background (CMB), light left over from the Big Bang. Although the CMB is extremely low in energy, relativity shows that from the perspective of the cosmic ray, these photons appear as highly energetic gamma rays. This transforms each encounter into a powerful nuclear reaction, similar to those recreated in laboratories at energies of tens of millions of electronvolts (MeV).

While photonuclear reactions have been studied for decades, research has mostly centred on heavier elements. For lighter nuclei, major gaps remain. These elements are not only abundant in cosmic rays but also present in biological materials, making them significant for both astrophysics and medicine. It is not enough to know that a nucleus can absorb energy from a gamma ray—scientists also need to understand what happens next. Does the nucleus re-emit

By measuring this energy loss, scientists can trace how far the particles have travelled and learn more about their origin.

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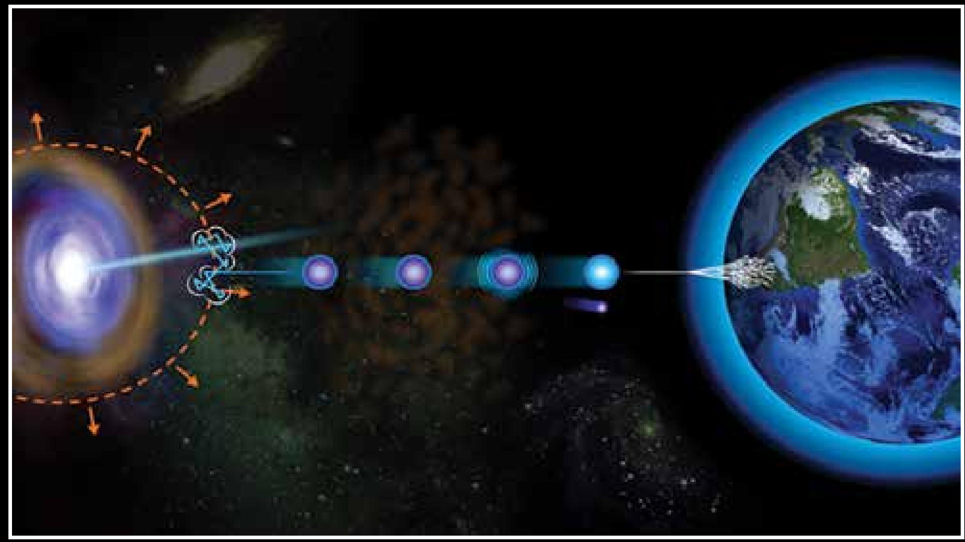

Figure 1 illustrates a typical result of particle decay energy plotted against the excitation energy of the nucleus. The research revealed that experimentally determined alpha particle decay spectra vary from model-dependent calculations.

light, or does it release particles such as neutrons, protons, or alpha particles that break it apart? Answering these questions is a central aim of the PANDORA Project.

The outcomes extend far beyond astrophysics. Accurate photonuclear data are vital for improving radiation shielding, developing advanced imaging systems, supporting medical isotope production, and understanding how radiation affects living tissue—all essential for nuclear medicine and safety.

To achieve this, experiments are being carried out at facilities worldwide. At NRF-iThemba LABS, the K600 magnetic spectrometer is used alongside detectors to study how nuclei respond and decay under extreme conditions. Similar experiments are under way at the Research Center for Nuclear Physics (RCNP) in Osaka, Japan, where the first series of measurements in 2024 focused on light nuclei such as carbon and boron.

These studies showed that experimental decay spectra differ from theoretical predictions, highlighting the importance of direct measurement. Future experiments are planned at RCNP in late 2025, followed by the NRF-iThemba LABS programme in 2026. Additional real photon experiments will take place at ELI-NP in Romania and HiGS in the United States.

By recreating cosmic processes here on Earth, the PANDORA Project connects the mysteries of the universe with practical technologies that benefit society. South Africa's contribution through NRF-iThemba LABS ensures that local expertise and facilities play a leading role in unlocking new knowledge at the frontier of science. SM

***Full research study:*** [arXiv:2211.03986v2]

PANDORA
Photo-Absorption of Nuclei and Decay Observation for Reactions in Astrophysics

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# AI AND DIGITAL TWINS
## Technologies Could Help Improve Health in Africa

**Public health aims to prevent disease, improve health, and help people live longer. The One Health approach, recommended by the World Health Organisation, links human, animal, and environmental health.**

This combined view helps to predict, prevent, and manage health threats more effectively. In Africa, the growth of digital health systems has opened new opportunities to use advanced tools such as artificial intelligence (AI) and digital twins, virtual models of real-world systems, to improve epidemic surveillance, prediction, and prevention.

Many low-resource African countries carry a heavy disease burden and face frequent outbreaks, lacking the infrastructure to respond effectively. Even with progress in digital health systems, it is still difficult to combine and use data from different sources in ways that are timely, accurate, and predictive. There is a need for advanced systems that can bring together health, environmental, and social data to improve outbreak response, predict risks, and promote overall well-being.

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A research study funded by the NRF looked at how AI and digital twin technologies could work together in an augmented AI system to improve health and well-being in these settings. The aim was to show how such a system could support decision-making, scientific knowledge discovery, and the sharing of data between different health systems.

To meet these aims, the researchers reviewed trends in AI and digital twin use in healthcare. They drew on over 10 years of experience in building digital health systems in Africa. They examined case studies, system designs, and research on cognitive digital twins, augmented AI, knowledge-based systems, and continual learning. From this, they proposed a system design in which AI and a 3D digital twin work together to support public health operations, such as those in Public Health Emergency Operations Centres (PHEOCs).

The study found that:

- Digital twins can model real-world health systems to enable real-time monitoring, prediction, and prevention. Cognitive digital twins (CDTs) incorporate AI, which allows them to learn, reason, and adapt. In public health, different sectors may have their own digital twins, which need to be connected for a full One Health picture.
- Augmented AI works with human experts, supporting rather than replacing them. AI can help find new patterns, test ideas, and adapt over time. Combining ontologies (structured knowledge) with Bayesian networks makes it possible to work with uncertainty and still support decision-making. Continual learning methods, such as Spatial-Temporal Graph Neural Networks (STGNNs), can detect changes and improve predictions and can also facilitate knowledge discovery.



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The proposed AI driven digital twin system has three layers:

1. **Monitoring** – Collects and merges data (health, environmental, and behavioural) using semantic technologies and shows data in context in a 3D digital twin.
2. **Situation analysis** – Detects and analyses situations using ontologies, Bayesian networks, and machine learning to for early warning of outbreaks and health risk assessment.
3. **Augmentation** – Uses AI to create, test, and refine theories about health events in partnership with the user, with recommendations displayed and contextualised in the 3D digital twin.

Cognitive digital twins (CDTs) incorporate AI, which allows them to learn, reason, and adapt.

The system fits within current PHEOC processes but adds new capabilities such as predictive modelling, interactive decision support, and clearer visual explanations.

The paper presents an ambitious vision for how AI and digital twins could change public health in low-resource countries. The 3D digital twin offers a powerful way to view and understand complex health problems. However, making this vision real will require overcoming both technical and social challenges, addressing ethical issues, and building systems that are sustainable and adaptable.

In conclusion, this approach has the potential to give early warnings, improve how resources are used, and make health responses more effective. SM

***Full research paper: https://ceur-ws.org/Vol-3541/***

![DID YOU KNOW?]

**DID YOU KNOW?** South Africa has one of the highest household debt levels in the world, with families owing 77 cents for every rand they earn. Many households borrow to cover basic needs, but rising living costs, high interest rates, and limited financial knowledge often leave them trapped in “isikoloto”, a cycle of debt that’s hard to escape. Research funded by the NRF shows that better financial education, transparent lending, fairer interest rates, and debt insurance could help families manage money more wisely and build a stronger economy.

***Full research study:***
***https://cberuk.com/cdn/conference_proceedings/2021-07-25-12-27-38-PM.pdf***

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# NEW STRATEGIES TO REDUCE
## Breast Cancer Mortality

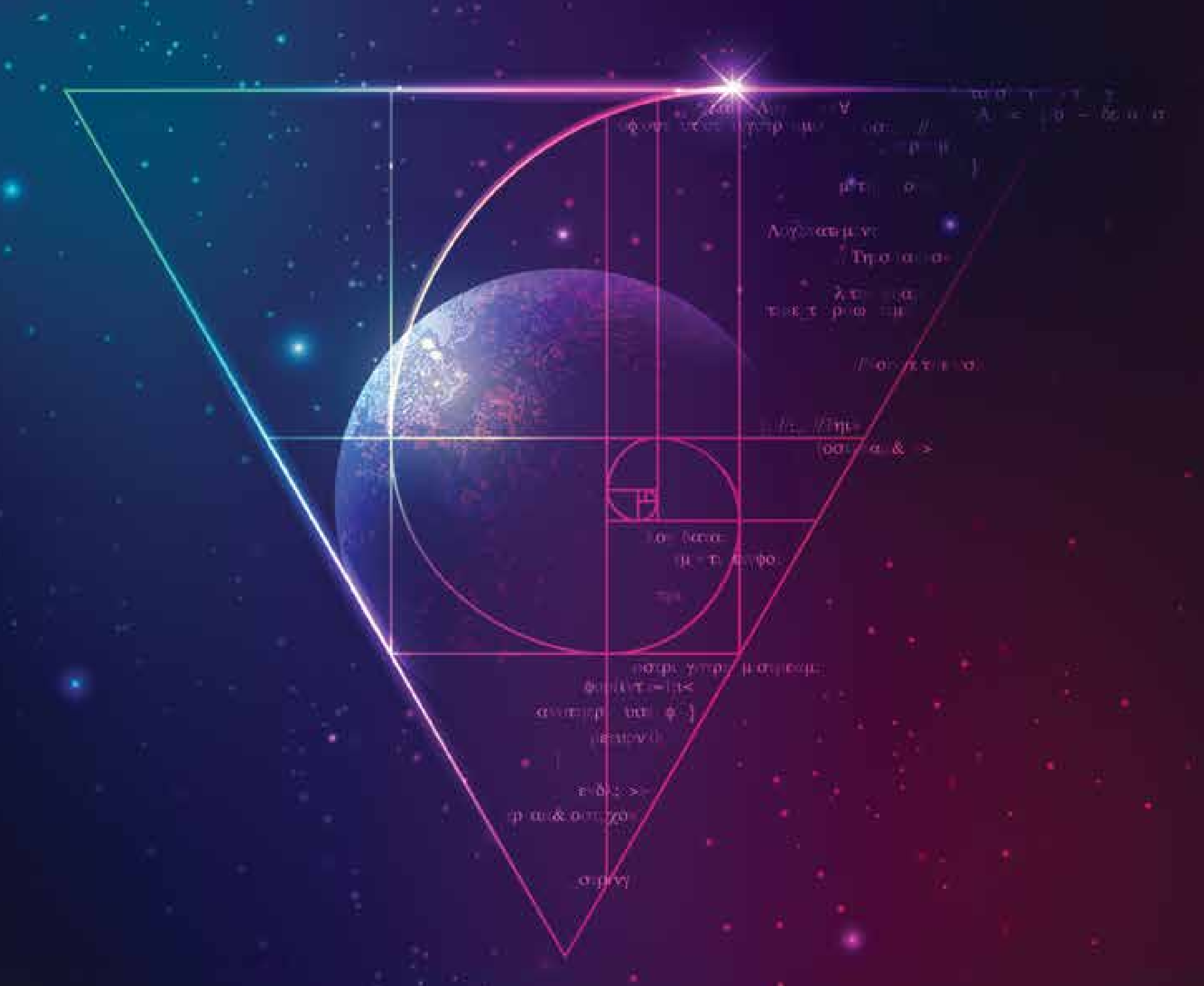
**Breast cancer remains the most common cancer in females in sub-Saharan Africa and is the second leading cause of death in females worldwide.**

A study funded by NRF-iThemba LABS and the Department of Higher Education probed alternative effective treatment approaches that offer the potential to significantly reduce mortality rates.

While lower incidences of breast cancer have been reported in South Africa compared to high income countries, the mortality rate is higher due to late-stage presentation and metastasis. Despite improved detection and treatment facilities in South Africa compared to other sub-Saharan African countries, overall breast cancer survival rates remain low with a five-year expected survival rate of 50%. Triple negative breast cancer in particular, characterised by aggressive phenotype and high metastatic potential, poses a significant challenge in oncology. Current treatment strategies such as hormonal therapy and chemotherapy have proved to be ineffective in patients with triple negative breast cancer.

Radiation therapy using X-rays or protons is commonly indicated alone or in combination with surgery to reduce the risk of recurrence and to improve breast cancer-specific survival. The dose of radiation that can be given to achieve tumour cure is often limited by the presence of normal tissues around the tumour. It has therefore become imperative to explore treatment strategies that can increase the effectiveness of the given radiation treatment with little effect on the surrounding non-cancerous tissues.

Histone acetylase inhibitors (HDACi) are chemical compounds that have been reported to have the potential to enhance radiation response mainly in cancerous cells but not in healthy cells. The aim of the in vitro study was to assess the efficacy of HDACi CUDC-101 to



"Science knows no country because it is the light that illuminates the world"

**- Louis Pasteur**

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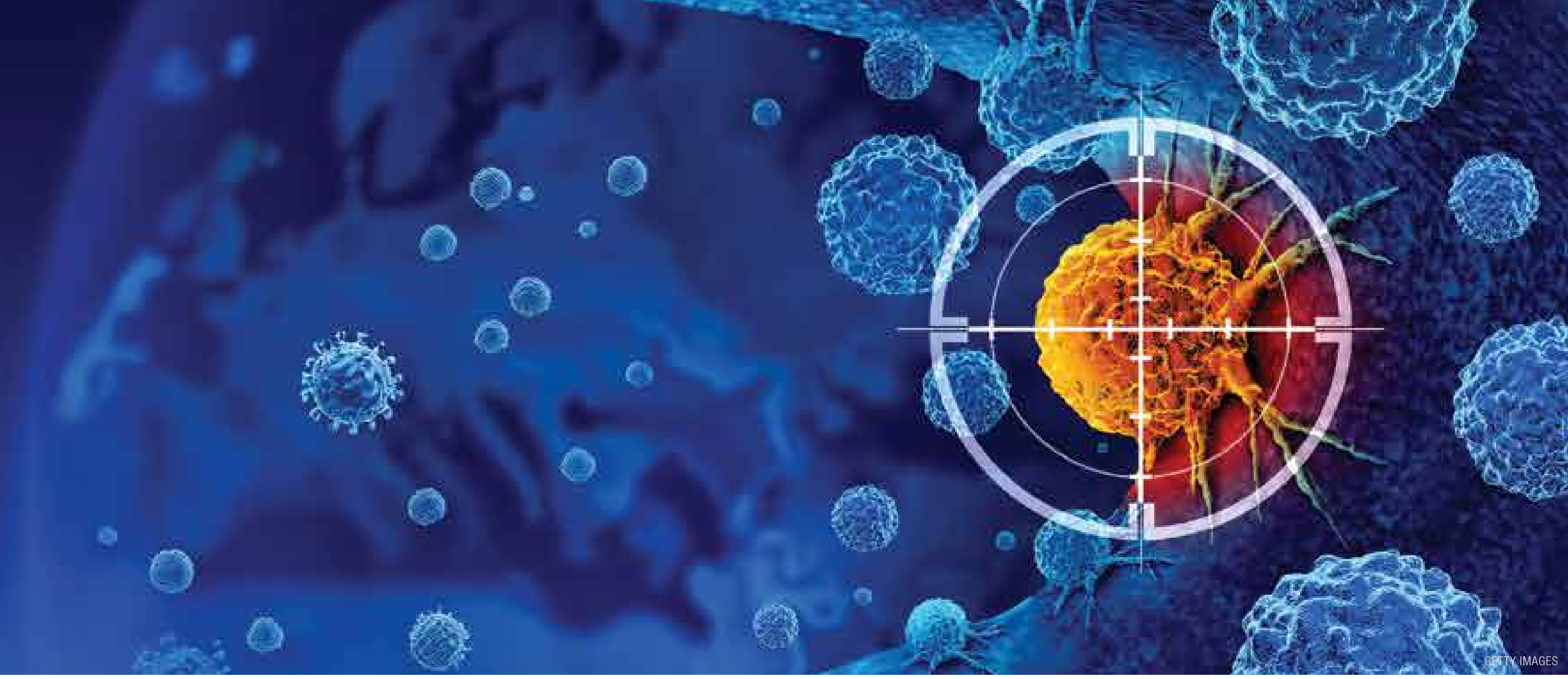
enhance response to x-irradiation and proton irradiation in the triple negative breast cancer (MDA-MB-231) and the estrogen, progesterone receptor positive (MCF-7) cell lines. The effect of the combination therapy on normal breast cells (MCF-10A) was also assessed. Consistent with the high metastatic potential of triple negative breast cancer, the researchers also investigated the effect of the HDACi alone or in combination with radiation in reducing the migration and invasion of cancer cells. This was particularly crucial in light of numerous reports regarding the metastasis-promoting effects of photon irradiation.

This was particularly crucial in light of numerous reports regarding the metastasis-promoting effects of photon irradiation.

### Key Findings of the Study

- Combination treatment of CUDC-101 and radiation resulted in more cell death compared to treatment with radiation alone, with sensitisation enhancement ratios (SER) of 1.77 and 2.09 after proton and X-radiation, respectively, in the triple negative breast cancer cell line. The higher SER after X-radiation is encouraging since x-ray therapy is more widely available compared to proton therapy.
- The increased cell death is explained by the observed increased, persisting unrepaired deoxyribonucleic acid (DNA) damage at 24-hours post-irradiation after combination therapy compared to radiation alone, mainly in the triple negative breast cancer cell line.
- CUDC-101 monotherapy and in combination with radiation reduced migration and invasion in the triple negative breast cancer cell line.
- The study demonstrated that combining HDACi CUDC-101 with radiation treatments has the potential to improve tumour control and survival in patients with triple negative breast cancer. The results of the study therefore serve as a first step toward the discovery of effective treatment for this breast cancer molecular subtype that is most prevalent in sub-Saharan populations. SM

***Full research study: https://doi.org/10.3390/ph17111467***



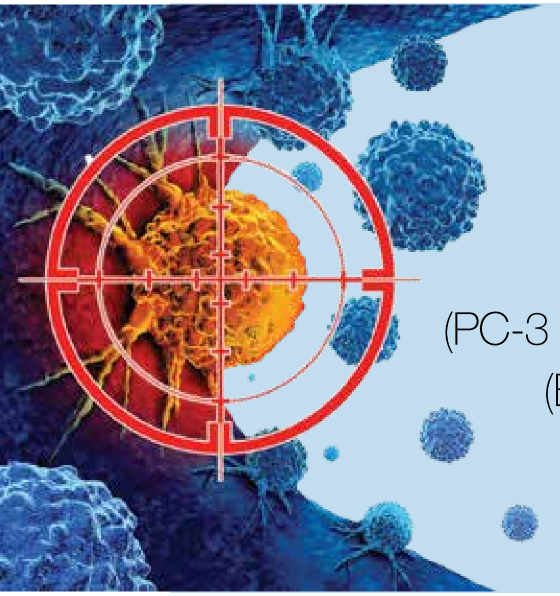
# SMARTER, SHORTER RADIATION for Prostate Cancer Patients in South Africa

***By Peter du Plessis, NRF iThemba LABS***

*Based on Exploring Hypofractionated Radiotherapy Efficacy in Prostate Cancer: In Vitro Insights, Radiation 2024, 4, 378–396. https://doi.org/10.3390/radiation4040029*

Prostate cancer is one of the most common cancers in men, and its treatment usually involves radiotherapy, giving patients many small doses of radiation over several weeks. This standard approach, called conventional fractionation, can be effective but it is time-consuming, exhausting for patients, and places a heavy load on healthcare systems. An alternative approach, recently investigated at NRF-iThemba LABS, is hypofractionated radiotherapy, where patients receive fewer treatment sessions but at higher doses each time. This method is attractive because it saves time and resources, but the big question is: does it work well, and is it safe for both cancerous and healthy cells?

The study aimed to test how prostate cancer cells respond to hypofractionated radiotherapy compared with the standard approach. Researchers exposed prostate cancer cells (PC-3 and DU-145) and non-cancerous prostate cells (BPH-1) to both treatment schedules, measuring growth, survival, DNA repair, and movement (invasion and migration).



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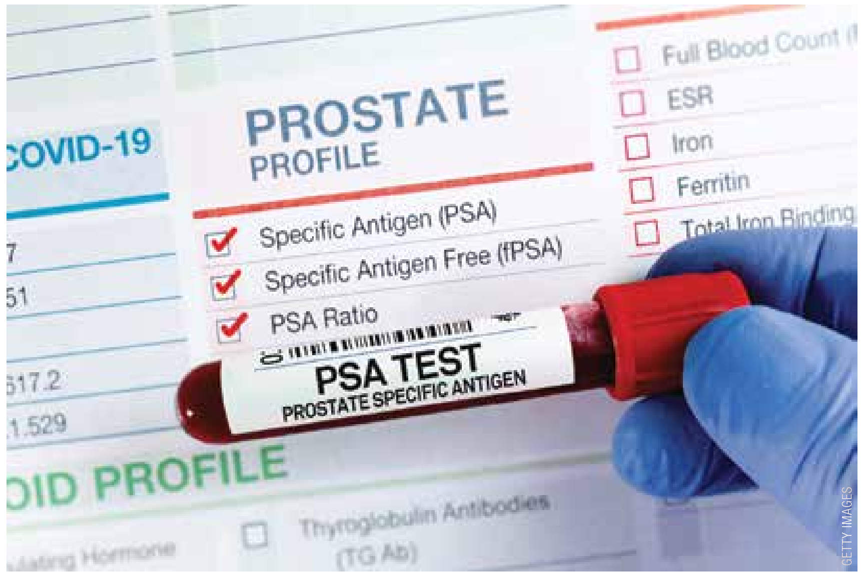


Lab results showed that healthy prostate cells were less damaged and recovered more effectively with shorter, high-dose treatments. Aggressive PC-3 cancer cells were more sensitive to hypofractionation, suggesting this method may better target harder-to-treat cases while sparing normal tissue. Cancer cell movement and invasion were also affected by the treatment, a positive sign for reducing recurrence.

### Key discoveries

Hypofractionation helped control aggressive cancer cells while being gentler on non-cancerous cells while conventional fractionation increased both invasion and damage in cancer cells.

For society, hypofractionated treatment reduces the number of hospital visits needed, a major advantage in resource-limited settings. It is also cost-effective and particularly useful during public health crises such as COVID-19.

These results are based on in vitro models, and clinical trials will be needed to confirm whether the same benefits occur in patients. However, the findings provide a strong foundation for future treatment innovation in South Africa.

The research concludes that fewer, smarter doses of radiation may lead to better results, fewer side effects, and shorter hospital stays, while at the same time making prostate cancer care more accessible to South African men. SM

# Physical Activity Profile of **HYPERTENSIVE ADULTS** Living in Rural South Africa

**Hypertension, or high blood pressure, is a serious global health concern and a leading cause of early death.**

In South Africa, the condition is widespread, especially in rural areas where more than half of adults are affected. Most people depend mainly on medication, but blood pressure control remains poor. Lifestyle changes such as regular physical activity are known to help, yet there is little information about the actual activity levels of adults with hypertension in rural South Africa.

A research study funded by the NRF was conducted to understand the patterns of physical activity among adults living with hypertension in a rural sub-district of Mpumalanga Province. The aim was to describe the frequency, intensity, duration, and type of activities performed over a seven-day period.

The researchers carried out a cross-sectional study in October 2021. Adults aged 40 years and older who had been diagnosed with hypertension were randomly selected from the Health and Ageing in Africa Longitudinal Study (HAALSI). A total of 429 participants completed the International Physical Activity Questionnaire Long Form (IPAQ-LF) through telephone interviews in their local language. The questionnaire covered five areas: work-related activity, transport, housework and family care, recreation or leisure, and time spent sitting. The participants' average age was 65 years. Women made up 58% of the group, and just over half reported having paid or unpaid work. The median total time spent on physical activity in a week was 330 minutes, including walking, moderate, and vigorous activities.

Work-related physical activity showed clear differences between men and women. Men reported more vigorous activity at work, with a median of 240 minutes per day compared to 120 minutes for women. Men also recorded more days per week of vigorous tasks. Women performed fewer vigorous tasks but did more moderate-intensity activities at work. Transport activity was also important. Both working men and women walked more frequently for transport than non-working participants. The amount of time spent in motor vehicles did not differ between men and women, and cycling was very uncommon across the group.

Household and caregiving activities were mainly performed by women. They reported more days of moderate-intensity tasks such as sweeping, washing, and gardening, both inside and outside the house, compared to men. Men, on the other hand, reported more vigorous household activities such as chopping wood or digging. Recreation and leisure activities were very low. Both men and women reported almost no time spent on exercise, sports, or other leisure physical activity. This highlights the limited opportunities for recreational exercise in rural areas. Time spent sitting was another key finding. Non-working men and women sat for longer periods during weekdays (around 180 minutes per day) than their working counterparts (about 120 minutes). Weekend sitting time was slightly higher than weekdays, but there was no significant difference between groups.

These findings suggest that public health interventions should consider these social and cultural factors when promoting physical activity to improve blood pressure control. SM

***Full research study: https://www.scielo.org.za/pdf/sajphys/v81n1/09.pdf https://www.scielo.org.za/pdf/sajphys/v81n1/09.pdf***



# **ENHANCING SCALABILITY** and Adaptability of Proactive Edge Caching Through Q-Learning


**With more video streaming, online gaming, and upcoming 6G networks, data demand is exploding. When you stream a video, scroll through social media, or download a file, it feels almost instant.**

However, behind the scenes, networks work hard to deliver that content quickly. One key trick is edge caching, i.e. storing popular content closer to users so it's ready the moment they request it.

But predicting what content people will want, and when, is tricky. Traditionally, engineers use models such as long short-term memory (LSTM) networks to forecast demand. These models can be accurate, but only if their "hyperparameters" (settings that control how the model learns) are carefully tuned. In real-world networks, where user behaviour changes constantly, tuning by hand is time-consuming and limits how adaptable the system can be.

A research study funded by the NRF developed a framework, called Scalable Proactive Adaptive Reinforcement Caching with Q-learning (SPARCQ), that uses Q-learning, a type of reinforcement learning, to automate this tuning process. Instead of human trial-and-error, the system learns by itself, adjusting its settings to keep predictions sharp in changing conditions.

To see how well SPARCQ worked, the team tested it using the MovieLens dataset, a popular benchmark for content prediction and recommendation systems. They compared it against:

i. Popularity-based caching (storing the most requested items).
ii. Untuned LSTM models (using default settings without optimisation).

The results show that SPARCQ improved the cache hit ratio (how often requested content was already stored at the edge) by an average of 8% over these baseline models. It also handled larger, more complex datasets with ease, proving that the method is scalable.

The findings also show that better caching doesn't just make your videos load faster, it reduces network congestion, saves bandwidth, and improves the overall user experience. By learning and adapting on its own, SPARCQ ensures that networks stay efficient even when demand patterns shift suddenly, like during major sporting events or viral content spikes. The research shows that automation through AI can make proactive caching smarter, faster, and more adaptable, without relying on constant human input.

That means future networks could deliver content more reliably, no matter how unpredictable our online habits become. SM

***Full research paper: Contact the DSTI-NRF Chair, Professor Nelishia Pillay, University of Pretoria, Pretoria, South Africa – nelishia.pillay@up.ac.za***
***https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=10980285***
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SCiENCE MaTTERS

## *Join Us on the Science Matters Podcast!*

As an NRF-funded researcher, are you ready to share your research insights and contribute to captivating conversations that ignite curiosity worldwide? If so, we're thrilled to invite you to be part of our podcast! Regardless of field or level of expertise, we welcome you to join our guest list. Simply email your research article(s) to sciencematters@nrf.ac.za or M.Sibiya@nrf.ac.za, and let's discuss your work in our studio. We're excited to collaborate with you and delve into the fascinating realms of science together.
We look forward to seeing you on our podcast!

# What if? . . .

This is the question that drives scientists to their laboratories and propels innovators ahead of their time. At the NRF, it is the question that introduces strategic thinking and steers action. For yesterday cannot answer today's problems and tomorrow cannot ask its challenges to be patient. South Africa needs people who regard this question as their mantra and organisations to help them explore the possibilities of potential. What if the solution were in your hands?

GALLO/GETTY IMAGES

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NRF National Research Foundation