

# Vascular Biomarkers: A Roadmap to Personalized Cardiovascular Health

## Executive Summary

Vascular biomarkers hold a profound impact in reshaping cardiovascular health management strategies. These critical indicators play a pivotal role in assessing the overall health of the cardiovascular system, providing valuable insights into potential risks and enabling early intervention measures. By measuring various biomarkers such as endothelial function, arterial stiffness, and inflammatory markers, healthcare professionals can gain a comprehensive understanding of an individual's cardiovascular status.

Importantly, by moving beyond traditional risk factors, healthcare professionals can offer personalized health assessments, tailoring recommendations based on individual vascular health. This information allows for personalized and targeted interventions, ranging from lifestyle modifications to pharmacological treatments. Additionally, the use of vascular biomarkers facilitates the monitoring of treatment effectiveness and the progression of cardiovascular diseases.

Seamless integration of vascular biomarkers into routine healthcare practices, including annual check-ups and preventive screenings, has emerged as a practical approach substantiated by reimbursement. The integration of data visualization tools enhances patient engagement during consultations, making complex information accessible, creating a collaborative relationship between healthcare professionals and patients. Vascular biomarkers also empower patients with specific, actionable insights, as evidenced by case studies showcasing the correlation between cardiovascular insights and positive lifestyle changes.

As research advances, the integration of innovative technologies and precision medicine approaches further enhances the significance of vascular biomarkers in tailoring interventions that address the specific needs of each patient. In essence, the incorporation of vascular biomarkers into cardiovascular health management marks a paradigm shift towards more proactive and individualized healthcare strategies.

*“The future of medicine lies in empowering patients with their own health data.”*

**DR. ERIC TOPOL**

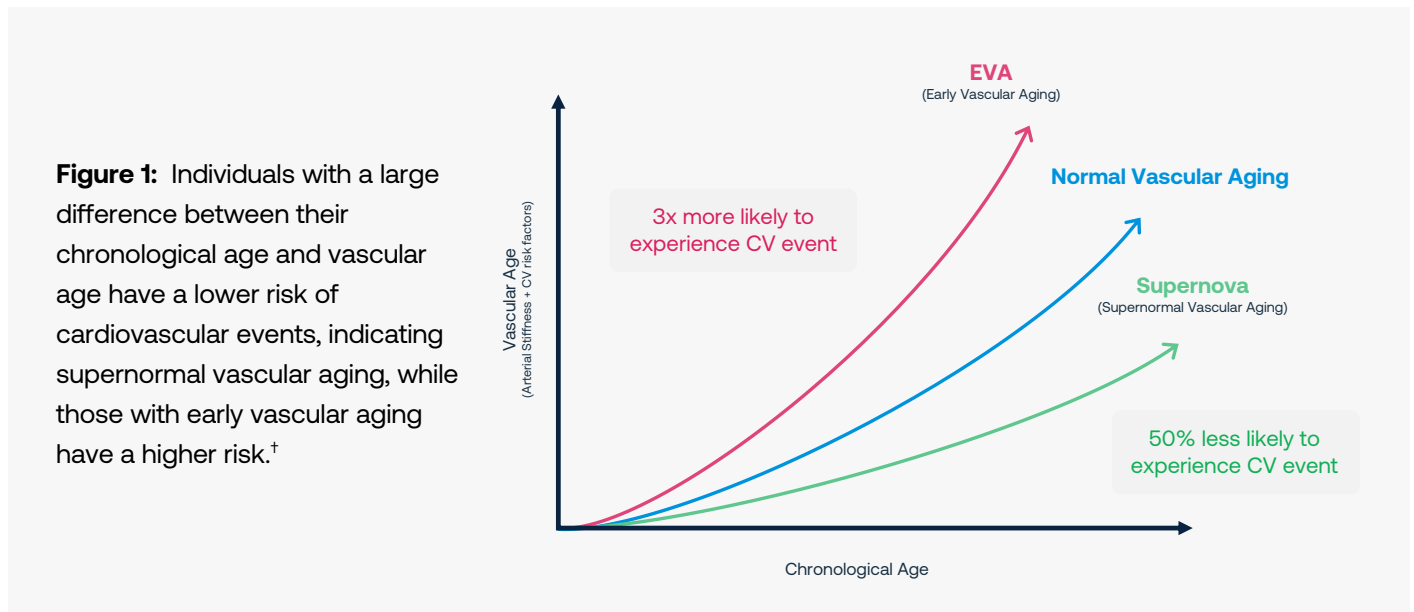
Founder and Director of the Scripps Research Translational Institute  
and author of *“The Patient Will See You Now”*

## Introduction:

In response to the evolving landscape of healthcare, there has been a noticeable shift in focus towards personalized and preventive approaches. This paradigm change represents a departure from the traditional one-size-fits-all model, recognizing the unique characteristics and needs of individual patients. Personalized healthcare emphasizes tailoring medical strategies to specific individuals, considering factors such as genetic makeup, lifestyle, and environmental influences. This shift is not only driven by advancements in medical technologies but also by a growing understanding of the intricate interplay between various factors influencing health outcomes.

At the forefront of this transformative approach is the recognition of vascular biomarkers as powerful tools for assessing cardiovascular health. These biomarkers, including measures of endothelial function, arterial stiffness, and blood flow patterns, provide a comprehensive and nuanced view of an individual's cardiovascular system. Unlike conventional diagnostic methods that often rely on generic risk factors, vascular biomarkers offer a more personalized assessment, enabling healthcare professionals to delve into the specific nuances of a patient's cardiovascular health. This precision is crucial for early detection of potential issues, allowing for targeted interventions and preventive measures tailored to the unique needs of each individual.

The integration of vascular biomarkers into cardiovascular health assessment represents a progressive step towards more individualized and effective patient care. As healthcare continues to embrace the era of personalized medicine, the use of these powerful biomarkers contributes to a more holistic understanding of cardiovascular health, fostering a proactive approach that can lead to better outcomes for patients. This shift not only benefits individual patients but also contributes to a broader transformation in healthcare towards a more patient-centric and preventive model.












<sup>†</sup> Bruno RM, Nilsson PM, Engström G, et al. Early and Supernormal Vascular Aging: Clinical Characteristics and Association With Incident Cardiovascular Events. *Hypertension*. 2020;76(5):1616-1624. doi:10.1161/HYPERTENSIONAHA.120.14971

## Understanding Vascular Biomarkers

Vascular biomarkers present a valuable avenue for understanding cardiovascular health. Determined non-invasively through pulse wave analysis using blood pressure cuffs and wearable sensors, the technique captures the subtle nuances of arterial stiffness by assessing the speed and contour of the pulse wave as it travels through the arteries. This analysis extracts vascular biomarkers representing the rigidity of blood vessels, reflecting their ability to expand and contract in response to changes in blood flow.

As part of a comprehensive cardiovascular health assessment, the insights gained from vascular biomarkers contribute to a more nuanced and proactive approach to patient care. Increased arterial stiffness is associated with aging and various cardiovascular risk factors, making it a crucial parameter for assessing the risk of hypertension, atherosclerosis, and other cardiovascular diseases. By incorporating pulse wave analysis to measure vascular biomarkers and arterial stiffness, healthcare professionals can pinpoint areas of concern and implement targeted interventions to mitigate the progression of vascular dysfunction. This approach aligns with the broader trend towards personalized medicine, enabling tailored strategies based on an individual's unique vascular profile.

**Table 1: CARDEIX vascular biomarkers representing arterial health**

	Heart Rate (HR)	A beat-to-beat heart rate measurement on par with standard ECG-based methods. A consistently high resting heart rate may be a sign of coronary heart disease.
	Brachial Blood Pressure	The pressure of blood at the brachial artery in the upper arm. High brachial blood pressure is a major risk factor for heart disease and stroke.
	Central Blood Pressure (SP & DP)	The pressure of blood at the root of the aorta in the heart. cBP is a more accurate predictor of subclinical cardiovascular disease than traditional brachial blood pressure alone.
	Central Pulse Pressure (PP)	The pressure which key organs like the heart, brain, and kidneys experience. It is used to identify the risk of end organ damage to major organs.
	Augmentation Pressure (AP)	A marker indicating how stiff one's artery is. Elevated augmentation pressure is associated with cardiovascular risk factors.
	Augmentation Index (Aix)	Another marker indicating how stiff one's artery is. It reflects the burden stiff arteries place on the heart.
	Subendocardial Viability Ratio (SEVR)	The supply of blood that flows to your inner heart muscle in relation to demand. It offers insight into how well a person's heart can handle the stress of exercise.
	Pulse Pressure Amplification (PPA)	The increase in amplitude of arterial pulse waves as they travel from central to peripheral arteries and provides insights into arterial stiffness, wave reflection, as well as the efficiency of blood flow distribution.
	Pulse Wave Velocity (PWV)	The speed at which the arterial pulse travels through the circulatory system, a key indicator of arterial stiffness.

*Through these biomarkers, healthcare practitioners can gain a comprehensive understanding of arterial stiffness and cardiovascular health, identifying early signs of vascular dysfunction that might otherwise go unnoticed.*

## Personalized Health Assessment

The power of vascular biomarkers lies in their ability to offer personalized information about arterial health, endothelial function, and blood flow patterns. Rather than categorizing individuals based on predetermined risk factors, healthcare professionals can tailor their recommendations and interventions to address the specific nuances of a patient's vascular profile. For example, vascular biomarkers enable the determination of early vascular aging, allowing clinicians to discern subtle changes in elasticity that may indicate early signs of vascular dysfunction.

This shift from a one-size-fits-all approach to a more individualized and precise healthcare strategy is transformative. It acknowledges that health is a deeply personal journey influenced by a myriad of factors unique to each individual. By leveraging vascular biomarkers, healthcare professionals can move beyond generic health advice and interventions, ensuring that recommendations are finely tuned to the specific needs and risks of the individual patient.

This personalized approach not only enhances the accuracy of health assessments but also fosters a collaborative relationship between healthcare providers and patients, where both parties actively participate in crafting strategies for optimal health outcomes. In essence, vascular biomarkers pave the way for a more patient-centric and tailored healthcare strategy, reflecting a paradigm shift towards a healthcare system that recognizes and respects the individuality of each patient.

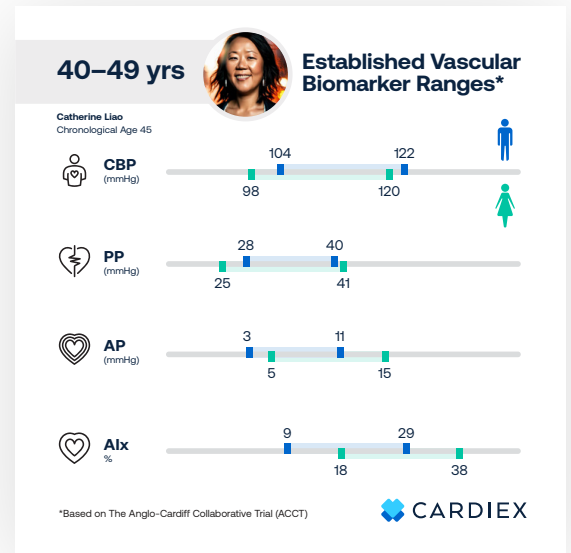
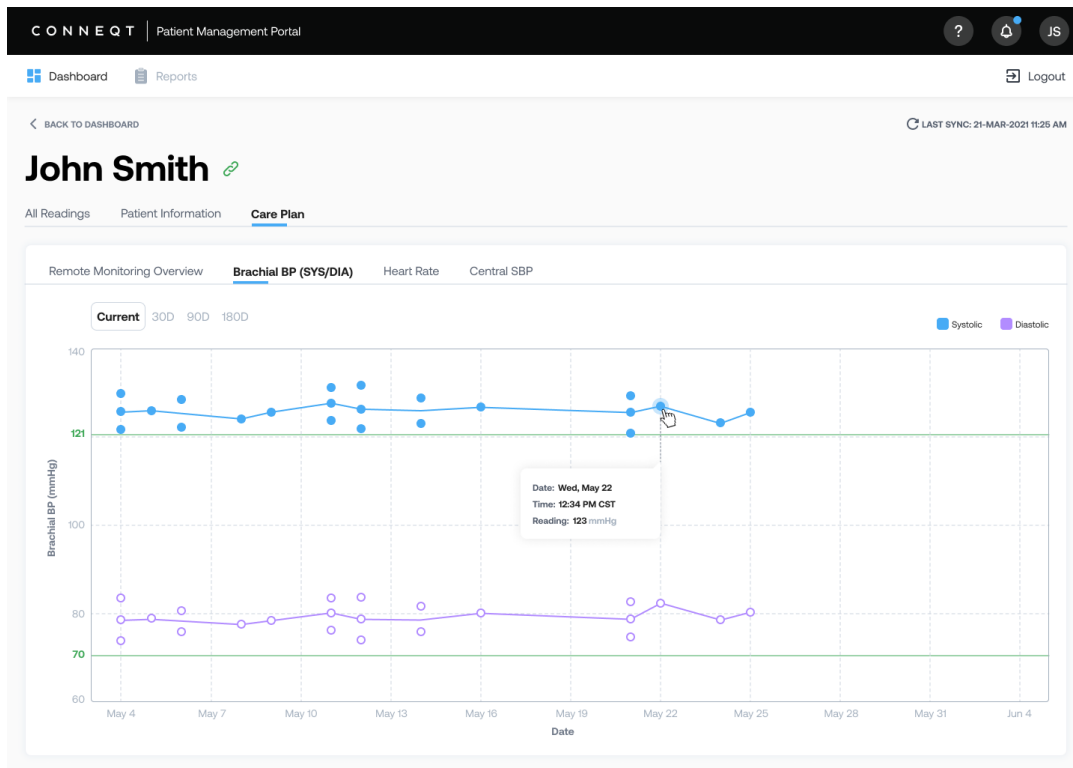


Figure 2: Normal, gender-based biomarker ranges for a 45-year-old.

## Engaging Patients through Data Visualization

The power of data visualization in the context of complex vascular biomarker data is transformative, providing a visual language that translates intricate information into a comprehensible and accessible format for patients. Graphs, charts, and interactive tools become indispensable instruments in conveying the nuances of vascular health assessments, making the intricate details easily understandable. For instance, a graph illustrating changes in arterial stiffness over time can vividly portray the dynamics of vascular health, allowing patients to grasp the significance of the data at a glance.

In patient consultations, healthcare professionals can leverage these visual aids to facilitate meaningful discussions and enhance patient comprehension. By employing charts depicting blood flow patterns or diagrams illustrating the impact of vascular biomarkers on overall cardiovascular health, clinicians can engage patients in a collaborative exploration of their unique vascular profiles. Interactive tools, such as virtual simulations or dynamic graphs, further enhance the learning experience by allowing patients to actively participate in understanding their health data. This visual approach not only demystifies complex medical information but also empowers patients to become active participants in their healthcare journey.



**Figure 3: Visualization of blood pressure trends of a patient being remotely monitored.**

Examples of effective data visualization in vascular health consultations may include before-and-after charts showcasing improvements in vascular biomarkers after lifestyle modifications or treatment interventions. Comparative graphs can highlight personalized risk assessments, demonstrating the impact of specific actions on reducing cardiovascular risks. These visuals serve as powerful tools for patient education, enabling healthcare professionals to convey complex concepts in a visually compelling manner. Ultimately, the integration of data visualization in patient consultations transforms the interaction into an informative and collaborative experience, fostering a deeper understanding of vascular health and motivating patients to take proactive measures for their overall well-being.

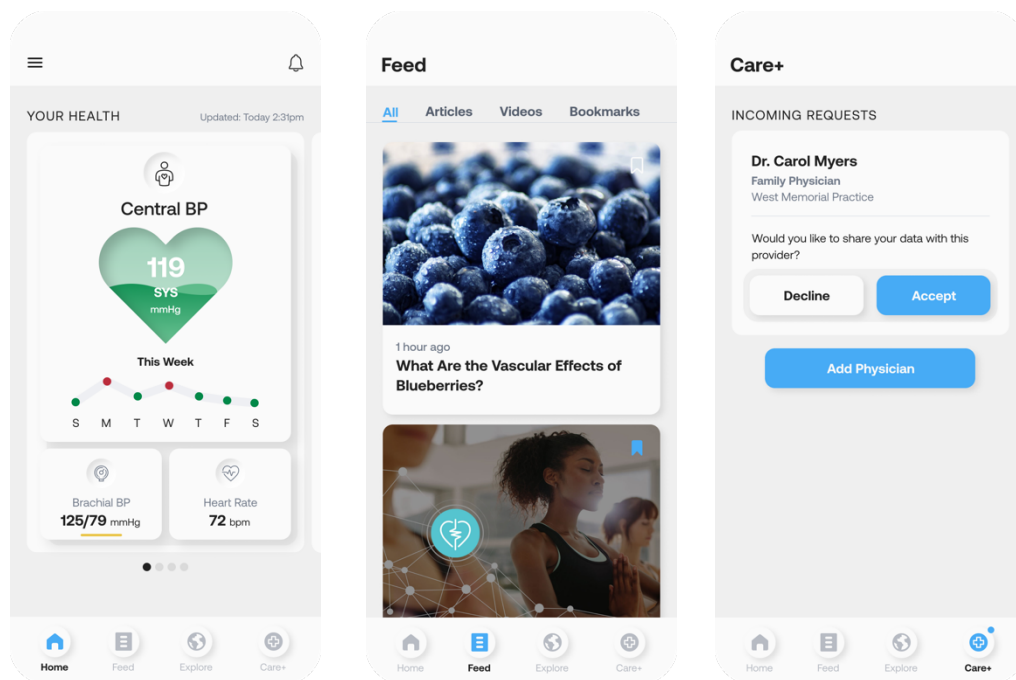
## Empowering Patients with Actionable Insights

Vascular biomarkers empower patients with actionable insights into their cardiovascular health. By elucidating specific aspects of vascular function, these biomarkers offer individuals a tangible understanding of their unique vascular health status and associated risks. Patient education becomes a pivotal component in this process, serving as a bridge to translate complex biomarker data into comprehensible information that empowers individuals to make informed decisions about their well-being.

In the realm of patient education, healthcare professionals play a crucial role in helping individuals interpret their vascular biomarker results. Through personalized consultations, clinicians can discuss the significance of biomarker values, linking them to potential cardiovascular risks. For instance, if arterial stiffness is elevated, the healthcare provider can explain how this may impact overall cardiovascular health and discuss strategies to mitigate these risks. By fostering a collaborative and educational environment, patients gain a deeper insight into their vascular health, enabling them to actively participate in the decision-making process regarding their care.

Illustrating the impact of vascular biomarker results through case studies or testimonials further reinforces the potential for positive lifestyle changes. Real-world examples of individuals who, armed with their biomarker data, made proactive decisions to adopt healthier lifestyles, such as incorporating regular exercise or adopting heart-healthy dietary habits, serve as powerful motivators. Testimonials that highlight tangible improvements in biomarker values following lifestyle modifications not only validate the effectiveness of these interventions but also inspire others to take charge of their cardiovascular health.

These stories of transformation underscore the actionable nature of vascular biomarkers, illustrating how they can serve as catalysts for positive behavior change. By coupling patient education with tangible examples of successful outcomes, healthcare professionals can instill a sense of empowerment in individuals, motivating them to view their vascular biomarker results not as static data points but as dynamic tools guiding them towards a healthier and more proactive approach to cardiovascular well-being.



## Building Trust Through Education

Building trust between healthcare professionals and patients is paramount, and education serves as a cornerstone in this process, particularly when it comes to vascular biomarkers. By transparently sharing knowledge about these biomarkers, clinicians establish a collaborative relationship that transcends the traditional doctor-patient dynamic. Educating patients about the intricacies of vascular biomarkers creates a foundation of understanding, allowing individuals to actively participate in their healthcare journey and make informed decisions.

For instance, explaining the significance of arterial stiffness or endothelial function in understandable terms empowers patients to appreciate the relevance of these biomarkers to their overall well-being. It instills a sense of ownership in individuals, fostering a mindset where they see themselves as partners in the decision-making process.

*Patient education not only enhances comprehension but also motivates patients to take an active role in managing their cardiovascular health.*

Successful patient engagement strategies often involve interactive educational sessions, where healthcare professionals use visuals, interactive tools, and personalized discussions to convey information about vascular biomarkers. For instance, workshops that allow patients to see and understand their own pulse wave analysis results or virtual simulations explaining blood flow patterns can significantly enhance engagement. Additionally, support groups and community initiatives that provide a platform for shared experiences and collective learning contribute to a sense of belonging and shared responsibility for cardiovascular health.

Through education, healthcare professionals not only provide information but also cultivate an environment where patients feel heard, respected, and valued. Such relationships become a driving force behind improved health outcomes, as patients are more likely to adhere to recommended lifestyle changes, treatment plans, and preventive measures when they are active participants in their healthcare journey. The success stories resulting from such patient engagement strategies further reinforce the transformative impact of building trust through education in the context of vascular biomarkers and cardiovascular health.

## **Integrating Vascular Biomarkers into Routine Healthcare**

Incorporating vascular biomarker assessments into annual check-ups offers numerous advantages. These assessments, including pulse wave analysis and measurements of arterial stiffness, provide clinicians with valuable information about an individual's cardiovascular health. This data can facilitate a more comprehensive risk assessment, allowing for the identification of subtle changes indicative of vascular dysfunction. The early detection of such issues enables timely interventions, reducing the risk of progression to more severe cardiovascular conditions.

### **Preventative Care**

Furthermore, integrating vascular biomarkers into preventive health screenings aligns with the broader goal of proactive healthcare. By routinely assessing vascular health as part of preventive care, healthcare professionals can identify potential cardiovascular risks at an early stage. This not only enhances individual patient care but also contributes to overall population health by addressing risk factors before they lead to more significant health challenges. Early detection and intervention have the potential to reduce the burden of cardiovascular diseases on healthcare systems and improve long-term health outcomes for the population.

### **Remote Patient Monitoring**

In the context of remote patient monitoring, connected vascular biomarker monitors further extend the reach of preventive healthcare strategies. Continuous monitoring of vascular health remotely allows for real-time data collection and analysis, enabling healthcare providers to track changes over time. This approach is particularly beneficial for individuals with chronic conditions or those at higher risk, providing a continuous stream of data for proactive management. Remote patient monitoring with connected vascular biomarker monitors enhances accessibility to healthcare, especially for individuals in remote or underserved areas, ensuring that preventive measures are not limited by geographical constraints.

The integration of vascular biomarkers into routine healthcare practices, including annual check-ups and preventive health screenings, is pivotal for advancing cardiovascular care. With reimbursement support for pulse wave analysis technologies, arterial health assessment becomes financially feasible for both in-clinic and remote patient monitoring. In clinic, such strategy enable early detection, proactive management, and improved population health outcomes. The incorporation of remote patient monitoring with connected vascular biomarker monitors extends the reach of preventive strategies, providing a comprehensive and holistic approach to cardiovascular health management.



## Conclusion

*The adoption of vascular biomarkers is more than a clinical strategy; it represents a paradigm shift towards a healthcare model that is personalized, patient-centric, and proactive.*

Vascular biomarkers emerge as a groundbreaking avenue for healthcare professionals to engage with patients on a deeper and more personalized level in the realm of cardiovascular health. The nuanced insights provided by biomarkers such as endothelial function, arterial stiffness, and blood flow patterns present a unique opportunity to convey intricate details about an individual's vascular health. These biomarkers serve as a dynamic tool during patient consultations, allowing clinicians to not only diagnose but also educate and motivate patients towards a proactive approach to cardiovascular well-being.

This transformative approach to patient engagement encourages healthcare professionals to fully embrace the integration of vascular biomarkers into routine cardiovascular health assessments. By seamlessly incorporating these biomarkers into regular practices, clinicians can unlock their potential to not only diagnose early signs of cardiovascular issues but also to educate and motivate patients towards proactive health management.

Embracing the innovative potential of vascular biomarkers aligns with the evolving landscape of healthcare, where a deeper understanding of individual health profiles becomes increasingly essential. By leveraging these biomarkers as tools for patient education, clinicians can bridge the communication gap, translating complex medical information into accessible insights. The encouragement for healthcare professionals to embrace this transformative approach is a commitment to empowering patients with actionable knowledge derived from their unique vascular profiles.

Ultimately, the integration of vascular biomarkers into routine cardiovascular assessments is not just about clinical diagnosis; it is a strategic move towards empowering patients to take control of their well-being. The vision for a healthcare future is one where patients are active participants in their health journeys, armed with personalized insights that transcend traditional diagnostic methods. As healthcare professionals embrace this innovative approach, vascular biomarkers become catalysts for a patient-centric, proactive, and collaborative model of cardiovascular care that holds the promise of improved outcomes and enhanced well-being.

## About CARDIEX

CARDIEX pioneered a biosensing technology that has been clinically validated and FDA-cleared to noninvasively measure vascular biomarkers representing key indicators of vascular health. The indicators include, but not limited to, central BP, vascular stiffness, vascular age, and heart stress. Named SphygmoCor®, the technology has been deployed in healthcare systems and clinical trials to measure arterial health.

The SphygmoCor technology enables a new paradigm in the diagnosis and management of hypertension and cardiovascular diseases that is increasingly decentralized and personalized. Incorporation of non-invasive measurements of vascular biomarkers can improve hypertension management in the following areas:

- Refine monitoring requirements;
- Reduce over-treatment;
- Improve under-treatment; and
- Reduce costs of management (e.g. medication costs, monitoring such as ambulatory blood pressure monitoring (ABPM))

When combined with cloud-based data analytics, our suite of FDA-cleared medical devices enables key stakeholders throughout the healthcare ecosystem to obtain valuable health information not accessible from standard brachial blood pressure monitors.

Learn more at [cardiex.com](https://cardiex.com).