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Review

The Influence of Arterial Stiffness in Heart Disease Patients: A Prognostic Role in Cardiac Surgery Procedures

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Abstract

Arterial stiffness has emerged as a significant predictor of postoperative complications in cardiac surgery patients. Therefore, this article explores how arterial stiffness determines adverse outcomes following cardiac surgery by reviewing the mechanisms linking arterial stiffness to complications such as acute kidney injury (AKI), myocardial ischaemia, and heart failure. Furthermore, this article discusses how impaired ventricular–arterial (V–A) coupling, driven by arterial stiffness, can hinder postoperative recovery and negatively impact long-term cardiovascular health. Current diagnostic techniques for measuring arterial stiffness are highlighted, along with potential interventions to mitigate the associated impact during the perioperative period. An improved understanding of the relationship between arterial stiffness and V–A coupling could lead to improved patient outcomes in cardiac surgery.

Keywords: arterial stiffness; cardiac surgery; postoperative complications; ventricular–arterial coupling

1. Introduction

For patients undergoing cardiac surgery, the interplay between pre-existing cardiovascular conditions and acute haemodynamic shifts during the procedure presents a significant challenge. Emerging evidence highlights arterial stiffness as a pivotal, frequently overlooked factor that has a significant impact on postoperative outcomes in this patient group.

Arterial stiffness is characterised by a loss of elasticity and compliance in the arterial wall in response to changes in blood pressure. It is most commonly assessed using pulse wave velocity (PWV), which measures the speed at which pressure waves travel through the arteries [1]. An increasing body of evidence confirms that arterial stiffness is a significant predictor of adverse postoperative complications, including acute kidney injury (AKI) [2], myocardial ischaemia [3], and heart failure [4]. These complications can have a substantial impact on recovery and long-term prognosis.

Furthermore, arterial stiffness is widely recognised as the primary clinical manifestation of, and a crucial indicator for, vascular ageing [5]. The progressive stiffening of large arteries significantly contributes to overall cardiovascular morbidity and mortality [6]. Structural changes, such as increased wall thickness and intima-media thickening (often associated with subclinical atherosclerosis), are independently linked to future cardiovascular events [7]. Beyond these structural alterations, the most prominent functional change in ageing large arteries is their inherent ‘stiffening’, which itself is a strong independent predictor of cardiovascular events [8]. This process directly contributes to age-related increases in systolic blood pressure and pulse pressure, both of which are closely associated with cardiovascular risk, particularly in elderly surgical patients [9].

Cardiac surgery places considerable hemodynamic stress on the cardiovascular system. Increased arterial stiffness exacerbates these challenges by impairing ventricular–arterial (V–A) coupling, the optimal synchronised interaction between the heart and arteries that is essential for effective haemodynamic adaptation [7]. Disruption to this coupling due to arterial stiffness can compromise postoperative recovery and lead to long-term complications.

This article reviews the clinical role of arterial stiffness in predicting and influencing postoperative complications in cardiac surgery patients. We examine its impact on cardiovascular coupling in this high-risk patient group and provide insights into potential strategies for improving clinical management and patient outcomes.

2. Methods for Measuring Arterial Stiffness in the Perioperative Setting

Several non-invasive techniques are available to assess arterial stiffness in the perioperative setting. The choice of method is typically guided by the specific clinical requirements, technical feasibility, and equipment availability.

2.1 Pulse Wave Velocity (PWV)

PWV is widely regarded as the “gold standard” for the non-invasive assessment of arterial stiffness. It relies on the biophysical principle that the pulse wave propagates faster through stiffer arterial vessels. Mathematically, it is defined as the distance traveled by the pulse wave divided by the transit time. Carotid–femoral PWV (cfPWV):

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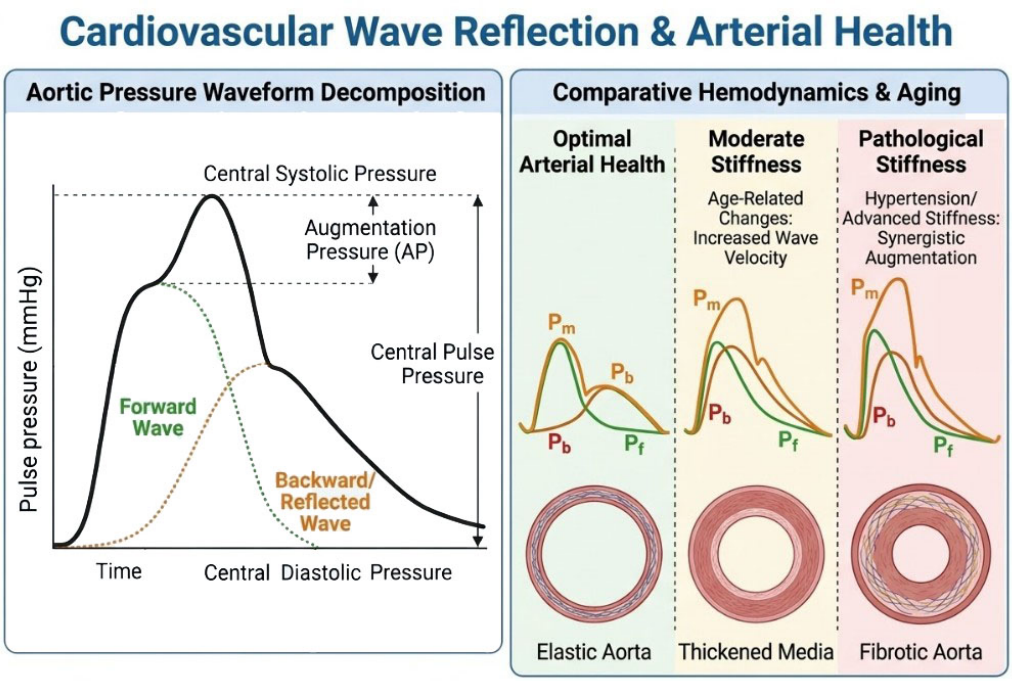


Fig. 1. Aortic pressure waveform decomposition and hemodynamic evolution with aging.

This technique assesses the stiffness of the aorta and large elastic arteries (e.g., from the carotid artery to the femoral artery). It is the most validated and clinically relevant parameter, with values of $\geq$10 m/s indicating an increased cardiovascular risk, according to the 2018 ESC guidelines [10]. Although this metric incorporates a composite of central and peripheral arterial segments, it offers the advantage of technical simplicity and is extensively used in clinical settings. According to the Asian Expert Society guidelines [11], brachial–ankle pulse wave velocity (baPWV) values are categorised as normal ($<$14 m/s), borderline (14–18 m/s), and abnormal ($>$18 m/s). Current research is investigating its utility in predicting anaesthesia-induced hypotension [11].

2.2 Augmentation Index (AIx)

AIx quantifies pulse wave reflection, indicating peripheral artery stiffness and the magnitude of the reflected wave returning to the aorta. AIx is measured via applanation tonometry (e.g., at the radial or carotid artery) and is derived from the difference between systolic peaks of the pulse wave [12]. It is expressed as a percentage of pulse pressure (Fig. 1). Elevated AIx (especially AIx75, normalised to a heart rate of 75 bpm) signifies increased cardiovascular risk. Measurements should be performed in resting patients in the supine position, avoiding recent intake of vasoactive substances or changes to/in medication.

2.3 Ambulatory Arterial Stiffness Index (AASI)

The AASI is derived from 24-hour ambulatory blood pressure monitoring (ABPM) and is calculated as 1 minus the regression slope of diastolic blood pressure on systolic blood pressure. A higher AASI indicates greater arterial stiffness under ambulatory conditions [12].

2.4 Cardio-Ankle Vascular Index (CAVI)

CAVI evaluates stiffness throughout the entire arterial system, from the origin of the aorta to the ankles. It is considered to be less dependent on acute blood pressure changes compared to PWV, rendering it valuable in the perioperative setting. Extensive validation confirms its prognostic value for cardiovascular and renal outcomes, including in the context of cardiac surgery [13].

2.5 Pulse Arrival Time (PAT)

PAT measures the time from the electrocardiogram (ECG) R-wave to the arrival of a pulse wave at a peripheral site. Although it is influenced by the cardiac pre-ejection period, it can be measured continuously, rendering it a promising tool for real-time, perioperative monitoring of arterial stiffness and haemodynamic [14].

3. Arterial Stiffness as a Predictor of Postoperative Complications

Elevated arterial stiffness is established as an independent risk factor for various postoperative complications in cardiac surgery patients, affecting a wide range of organ systems (Fig. 2).

3.1 Impact on Kidney Function

AKI is one of the most common and severe complications following cardiac surgery. It is associated with in-

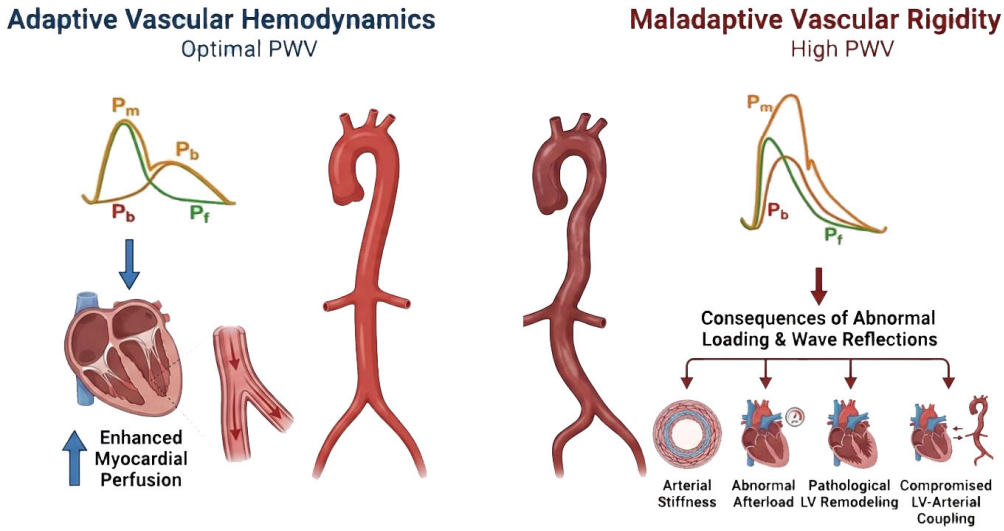


Fig. 2. Comparative analysis of vascular hemodynamics and arterial stiffness. LV, left ventricular; PWV, pulse wave velocity.

creased morbidity, mortality, and healthcare costs. Arterial stiffness compromises the capacity of the kidneys to maintain adequate blood flow during periods of haemodynamic instability, thereby increasing the risk of AKI. Studies have shown that an elevated baseline level of arterial stiffness is associated with a greater risk of AKI, which in turn worsens patient outcomes and extends hospital stays.

Choi et al. [2] demonstrated that preoperative baPWV is an independent predictor of AKI development following off-pump coronary artery bypass grafting (OPCABG). A baPWV value of at least 1720 cm/s was associated with a significantly higher risk of AKI. Similarly, Greenwood et al. [15] reported that cfPWV is an independent predictor of AKI after coronary artery bypass grafting. Each 1 m/s increase in cfPWV was associated with a 1.48-fold increased risk of AKI. The proposed mechanisms for this association include increased vulnerability of the renal microvasculature to blood pressure fluctuations due to reduced buffering capacity of large arteries, impaired renal autoregulation, and systemic inflammatory responses associated with stiffened vessels. Moreover, Hori et al. [16] demonstrated that broader vascular dysfunction, including impaired endothelial function (flow-mediated dilation, FMD), was found to be associated with AKI after cardiac surgery, suggesting a comprehensive vascular pathway to renal damage.

Limited evidence also links arterial stiffness to early postoperative complications. Greater preoperative PWV is associated with a higher incidence of cardiac surgery-associated acute kidney injury (CSA-AKI) in patients undergoing valve surgery.

3.2 Myocardial Ischaemia and Heart Failure

Arterial stiffness impairs coronary artery perfusion, increasing the risk of ischaemic events during and after surgery. Furthermore, myocardial workload is increased to overcome the increased afterload caused by stiffened arteries [17], predisposing the patient to a higher risk of developing heart failure postoperatively. This relationship is critical, as the increased left ventricular afterload imposed by stiff arteries reduces left ventricular efficiency and is a direct contributor to complications such as heart failure or inadequate myocardial ischaemia during the recovery phase [6,18,19].

3.3 Neurological Implications

Neurological complications such as stroke, postoperative cognitive dysfunction (POCD), and delirium can have devastating consequences following cardiac surgery. Arterial stiffness can play a crucial role in cerebral haemodynamics and autoregulation. Impaired regulation of blood flow to the cerebral autoregulation due to stiffer arteries may lead to suboptimal perfusion, particularly during periods of low cardiac output or circulatory instability following surgery.

Obata et al. [20] found a significant positive correlation between preoperative AASI and the lower limit of cerebral autoregulation (LLA) during cardiac surgery. A higher AASI was associated with a higher LLA, indicating that cerebral blood flow became pressure-dependent at higher mean arterial pressures. This suggests that patients with stiffer arteries may have a narrower range of mean arterial pressure (MAP) at which cerebral blood flow is maintained, potentially increasing their risk of cerebral hypoperfusion during periods of hypotension. Furthermore, Hori et al. [16] further explored this phenomenon, demonstrating that impaired endothelial function (as assessed by FMD) and increased baPWV were both independently associated with a higher LLA. This underscores that vascular stiffness directly impacts the brain's ability to maintain stable blood flow despite systemic blood pressure changes, increasing

its vulnerability to hypotensive insults during cardiovascular surgery. A recent large cohort study [20] emphasises the critical role of blood pressure control in preventing postoperative delirium. This supports the importance of considering individual LLA (influenced by arterial stiffness) when setting intraoperative blood pressure targets, especially for patients with pre-existing vascular stiffness.

3.4 Postoperative Atrial Fibrillation (POAF)

Postoperative atrial fibrillation (POAF) is the most common arrhythmia after cardiac surgery. It is associated with an increased risk of stroke, prolonged hospitalisation, and higher healthcare costs. Emerging evidence suggests a link between arterial stiffness and the development of POAF. A recent study by Plunde et al. [21] identified that CAVI may be an independent predictor of POAF following cardiac surgery. This finding is biologically plausible, suggesting that a stiffer arterial system contributes to increased left ventricular afterload and subsequent left atrial remodelling—a key component of the pathophysiological pathway leading to POAF [22].

3.5 Long-Term Mortality and Morbidity

Arterial stiffness influences long-term outcomes after cardiac surgery, beyond immediate postoperative complications. Tanaka et al. [18] demonstrated that preoperative CAVI is an independent predictor of adverse long-term outcomes, including all-cause and cardiovascular mortality, in patients undergoing transcatheter aortic valve replacement (TAVR). Patients with elevated CAVI exhibited reduced survival rates. The general prognostic value of arterial stiffness has been well established by meta-analyses such as those by Vlachopoulos et al. [6] for PWV and Tavolinejad et al. [22] for CAVI, and this extends to the cardiac surgical population. Importantly, arterial stiffness is not merely a passive marker of pre-existing cardiovascular disease, but actively contributes to disease progression and susceptibility to adverse events, even following successful surgery [4] (Fig. 3).

4. Pathophysiological Mechanisms and Cardiovascular Coupling

The pathophysiological mechanisms through which arterial stiffness contributes to postoperative complications are complex and multifactorial. These include altered vascular compliance, increased left ventricular afterload, and impaired baroreceptor sensitivity. Together, these factors can lead to instability in the immediate postoperative period and long-term cardiac dysfunction [23].

V–A coupling defined as the optimal interaction between the heart and the arterial system, is crucial for maintaining efficient circulation and adequate tissue perfusion [24]. The heart and arteries interact to deliver the precise amount of blood to organs based on their metabolic needs. However, during cardiac surgery, the cardiovascular system undergoes acute haemodynamic changes, including fluctuations in blood pressure and heart rate. Arterial stiffness impairs the arteries' ability to adapt to these changes, creating a mismatch between the heart's output and the arterial system's capacity to receive and distribute blood. This significantly increases the myocardial workload, resulting in inefficient circulation and compromised recovery [25]. Arterial stiffness particularly affects left ventricular function. In the presence of arterial stiffness, the left ventricle encounters increased afterload, hindering its ability to eject blood effectively. This reduces the left ventricle's efficiency and can result in complications such as heart failure or a low cardiac output during the recovery phase following surgery [26].

Disruption to V–A coupling caused by arterial stiffness can have significant implications for postoperative recovery. Impaired V–A coupling can result in prolonged hospital stays, an increased risk of heart failure, and a higher likelihood of readmission after surgery [27]. Monitoring V-A coupling in cardiac surgery patients could help identify those at higher risk of adverse recovery and guide more personalised treatment strategies [28].

5. Impact of Cardiac Surgery on Arterial Stiffness and Vice Versa

The relationship between arterial stiffness and cardiac surgery is bidirectional: pre-existing stiffness can influence surgical outcomes, while the procedure itself can also modulate arterial stiffness. Some cardiac surgical interventions, particularly those addressing valvular heart disease, can directly impact arterial stiffness. Plunde and Bäck [19] reviewed the impact of aortic valve replacement (AVR) on arterial stiffness in patients with aortic stenosis (AS). They observed that AS is inherently associated with increased arterial stiffness and that both surgical (SAVR) and transcatheter (TAVR) AVR can significantly reduce arterial stiffness. This improvement was attributed to the immediate reduction in left ventricular afterload, which leads to favourable remodelling of the left ventricle and the arterial tree. On the other hand, Sigala et al. [29] investigated whether the type of surgical valve (mechanical vs. biological) affects the impact of SAVR on arterial stiffness. Miki et al. [30] specifically examined the clinical implications of CAVI before and after TAVR, observing that CAVI typically decreases after TAVR (indicating reduced stiffness). They demonstrated that the magnitude of this decrease and post-procedural CAVI values were important predictors of long-term outcomes such as left ventricular diastolic dysfunction and late cardiac events. Investigating the reasons for the decline of CAVI in aortic valve stenosis, Takahashi et al. [31] sought to elucidate the mechanisms behind these changes. They noted that while AVR improves arterial stiffness, the residual stiffness or the extent of its reduction remains prognostically relevant.

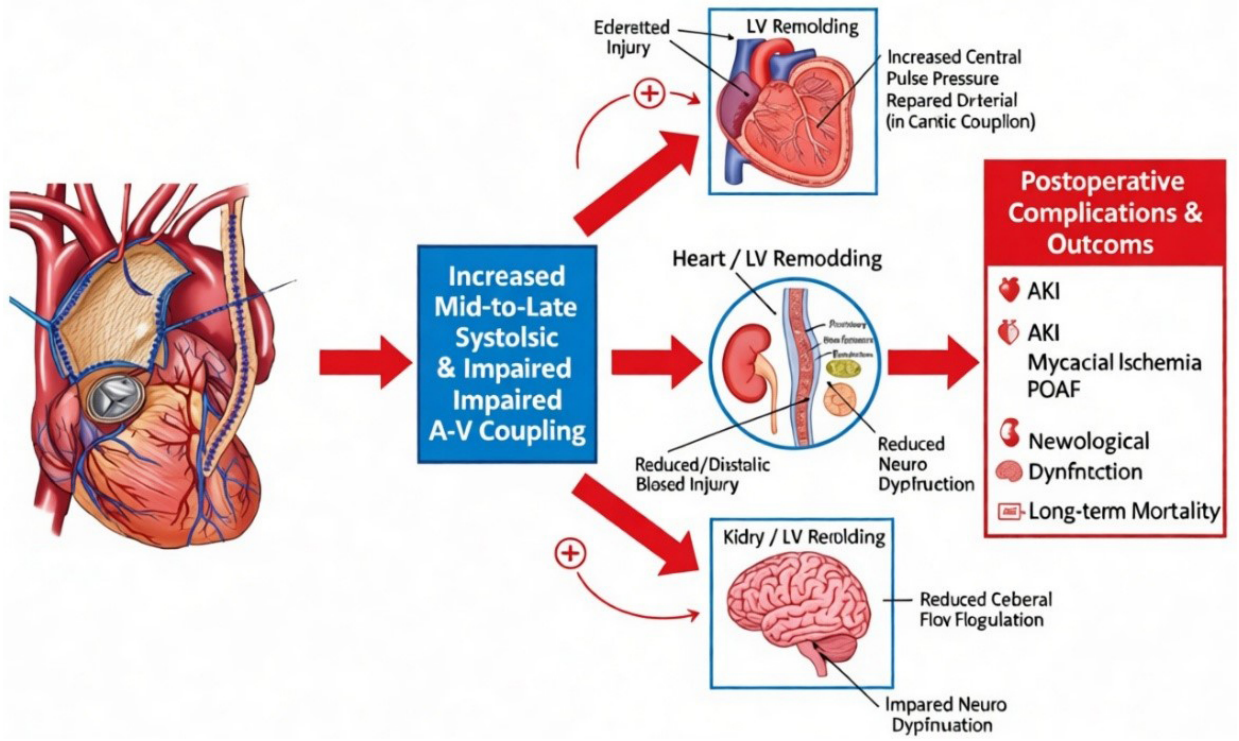


Fig. 3. Mechanism by which arterial stiffness influences outcomes in patients undergoing cardiac surgery.

Notably, preoperative CAVI is often lower in individuals with aortic stenosis or regurgitation compared to those with isolated ascending aortic dilation. This difference may reflect altered haemodynamics that mask underlying arterial rigidity. However, a significant increase in CAVI is observed after surgery, particularly in patients with aortic stenosis. This increase might be related to the relief of valvular obstruction, causing the arterial tree to operate at a higher pressure.

6. Management and Strategies to Modulate Arterial Stiffness and V-A Coupling

Elevated arterial stiffness can present significant challenges during cardiac surgery and subsequent patient management. For instance, patients with severe arterial stiffness may have a reduced capacity for vasodilation, which complicates blood pressure management and increases the risk of hypertension and hypoperfusion. Understanding a patient's baseline arterial stiffness could inform anaesthetic decisions, particularly regarding the selection of vasopressors and vasodilators, and help establish more personalised haemodynamic targets throughout the various stages of surgery and recovery.

Intraoperative monitoring of V–A coupling, although less commonly employed, could provide real-time insights into cardiovascular performance to facilitate optimal management. Devices that measure central haemodynamics, including arterial pressure and cardiac output, can assess the efficiency of V–A coupling during and after surgery. This dynamic assessment could guide immediate adjustments to treatment strategies, potentially preventing complications [32].

Given the adverse effects of arterial stiffness, interventions aimed at modulating it during the perioperative period are of significant interest. Kepler et al. [33] conducted a randomised clinical trial investigating the effect of remote ischaemic preconditioning (RIPC) on arterial stiffness in patients undergoing vascular surgery. They demonstrated that RIPC reduced the increase in arterial stiffness observed 24 hours after surgery in the control group, suggesting a potential protective effect on vascular health. Although this study focused on vascular surgery, the implications for cardiac surgery, which also involves significant ischaemia-reperfusion injury, are promising. Further research in cardiac surgical cohorts is needed to establish whether RIPC or other preconditioning strategies could similarly mitigate perioperative arterial stiffening and improve outcomes.

7. Clinical Implications and Future Perspectives

The growing body of evidence strongly supports the integration of arterial stiffness assessment into the clinical management of cardiac surgical patients.

7.1 Role in Preoperative Risk Stratification

Preoperative measurement of arterial stiffness, particularly cfPWV, baPWV, or CAVI, could be a valuable tool for enhanced risk stratification. Identifying patients

with elevated arterial stiffness could help to stratify those at increased risk of multiple postoperative complications, including AKI [34], neurological deficits such as delirium [35] and stroke [20], and adverse long-term cardiovascular events such as postoperative atrial fibrillation [21]. This would enable clinicians to implement more intensive monitoring strategies, adapt anaesthetic management (e.g., by setting individualised blood pressure targets guided by LLA) and potentially initiate protective interventions prior to surgery.

Furthermore, preoperative assessment of arterial stiffness using CAVI has demonstrated prognostic value in patients undergoing coronary artery bypass grafting (CABG). Patients with pathological CAVI ($\geq$9.0) before CABG exhibited a significantly higher incidence of adverse events and mortality during the five-year follow-up period (48.86% versus 34.9%, $p = 0.034$, and 4.55% versus 0.67%, $p = 0.049$, respectively) compared to those with normal CAVI values ($<$9.0) [3]. Additionally, pathological CAVI, along with multifocal atherosclerosis, was identified as an independent predictor of the composite endpoint. Multivariate analysis identified elevated CAVI and carotid stenosis as independent predictors of mortality and major adverse cardiac events (MACE), demonstrating the usefulness of incorporating arterial stiffness measurement for risk stratification.

7.2 Potential for Targeted Interventions

Identifying high-risk patients characterized by increased arterial stiffness enables the implementation of targeted interventions. Although pharmacological strategies to reduce arterial stiffness preoperatively are still under investigation, alternative approaches could be considered, such as strict blood pressure control [23], optimisation of glycaemic control [36], and preconditioning strategies (e.g., RIPC, as explored by Kepler et al., 2019 [33]) [37]. Furthermore, understanding how stiffness influences a patient's LLA could inform more personalised blood pressure targets during and after surgery, helping to prevent cerebral hypoperfusion [27]. The emerging link with POAF also suggests the potential for early antiarrhythmic strategies or enhanced monitoring for these high-risk individuals [21].

Renal impairment is both a consequence of and a predictor of increased arterial stiffness. Elevated PWV is associated with a reduced eGFR both before and after cardiac surgery [38]. This association remains significant even after adjusting for factors such as age and hypertension, suggesting that arterial stiffness may contribute to renal dysfunction by increasing pulsatile load and microvascular damage [39]. Increased/elevated postoperative arterial stiffness can also exacerbate renal impairment, thereby influencing prognosis [15]. However, further research is required to establish whether interventions aimed at improving vascular function, such as the use of cholesterol-lowering drugs, antihypertensive therapy, smoking cessation, angiotensin-converting enzyme inhibitor therapy, vitamin E supplements, statins, and L-arginine therapy, could prevent CSA-AKI [40,41].

7.3 Need for Large, Multicenter Prospective Studies

While the current evidence is compelling, much of it is derived from single-centre or retrospective studies. To establish the clinical utility of measuring arterial stiffness, large, multicentre prospective studies are essential. These studies should validate the predictive value of various arterial stiffness parameters across diverse cardiac surgical populations, evaluate the cost-effectiveness of routine assessment, and investigate whether interventions guided by arterial stiffness measurements can improve patient outcomes. Specific areas for future research include determining the optimal timing for assessing arterial stiffness, identifying the most suitable parameters for specific complications, and establishing the definitive high-risk threshold.

7.4 Development of Continuous Monitoring Technologies

The development of non-invasive, continuous monitoring technologies for arterial stiffness, such as PAT [42], shows great potential. These technologies could provide real-time feedback on vascular health and haemodynamic status during the perioperative period, enabling timely treatment adjustments and potentially preventing complications. Further research into the accuracy, reliability, and clinical utility of these emerging technologies in operating theatres and intensive care units is crucial. An example of such advancement is the ongoing clinical trial [43] using ultrasonic PWV measurement, which aims to explore the real-time interaction between arterial stiffness, haemodynamics, and anaesthesia.

8. Conclusion

In conclusion, arterial stiffness represents a critical prognostic factor, significantly influencing postoperative complications and cardiovascular outcomes following cardiac surgery. By impairing the arterial buffering capacity, arterial stiffness compromises V–A coupling, thereby increasing the risk of major complications, including AKI, myocardial ischaemia, heart failure, and stroke. Monitoring arterial stiffness and V–A coupling before and during surgery provides valuable prognostic information and could guide more effective perioperative management. Further research is warranted to explore potential interventions capable of reducing arterial stiffness and optimising V–A coupling, with the ultimate aim of enhancing postoperative recovery and long-term outcomes for patients undergoing cardiac surgery.

Author Contributions

FA, GP, AG, and MF made substantial contributions to the conception and design, or acquisition of data, or analysis and interpretation of data; FA, GP, AG, and MF have been

involved in drafting the manuscript or reviewing it critically for important intellectual content; all authors have given final approval of the version to be published; and all authors have agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics Approval and Consent to Participate

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Conflicts of Interest

The authors declare no conflicts of interest.

Declaration of AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used Gemini to generate the visual elements for Figs. 1,2,3 and Adobe Photoshop to refine them. The authors reviewed and edited the content as necessary and take full responsibility for the content of the publication.

References

[1] Schillaci G, Battista F, Settimi L, Anastasio F, Pucci G. Cardio-ankle vascular index and subclinical heart disease. Hypertension Research: Official Journal of the Japanese Society of Hypertension. 2015; 38: 68–73. https://doi.org/10.1038/hr.2014.138

[2] Choi JS, Oh SJ, Sung YW, Moon HJ, Lee JS. Pulse wave velocity is a new predictor of acute kidney injury development after off-pump coronary artery bypass grafting. PloS One. 2020; 15: e0232377. https://doi.org/10.1371/journal.pone.0232377

[3] Sumin AN, Shcheglova AV, Ivanov SV, Barbarash OL. Long-Term Prognosis after Coronary Artery Bypass Grafting: The Impact of Arterial Stiffness and Multifocal Atherosclerosis. Journal of Clinical Medicine. 2022; 11: 4585. https://doi.org/10.3390/jcm11154585

[4] Aboyans V, Frank M, Nubret K, Lacroix P, Laskar M. Heart rate and pulse pressure at rest are major prognostic markers of early postoperative complications after coronary bypass surgery. European Journal of Cardio-thoracic Surgery: Official Journal of the European Association for Cardio-thoracic Surgery. 2008; 33: 971–976. https://doi.org/10.1016/j.ejcts.2008.01.065

[5] Oliveira AC, Cunha PMGM, Vitorino PVDO, Souza ALL, Deus GD, Feitosa A, et al. Vascular Aging and Arterial Stiffness. Arquivos Brasileiros De Cardiologia. 2022; 119: 604–615. https://doi.org/10.36660/abc.20210708

[6] Vlachopoulos C, Aznaouridis K, Stefanadis C. Prediction of cardiovascular events and all-cause mortality with arterial stiffness: a systematic review and meta-analysis. Journal of the American College of Cardiology. 2010; 55: 1318–1327. https://doi.org/10.1016/j.jacc.2009.10.061

[7] Ikonomidis I, Aboyans V, Blacher J, Brodmann M, Brutsaert DL, Chirinos JA, et al. The role of ventricular-arterial coupling in cardiac disease and heart failure: assessment, clinical implications and therapeutic interventions. A consensus document of the European Society of Cardiology Working Group on Aorta & Peripheral Vascular Diseases, European Association of Cardiovascular Imaging, and Heart Failure Association. European Journal of Heart Failure. 2019; 21: 402–424. https://doi.org/10.1002/ejhf.1436

[8] Ben-Shlomo Y, Spears M, Boustred C, May M, Anderson SG, Benjamin EJ, et al. Aortic pulse wave velocity improves cardiovascular event prediction: an individual participant meta-analysis of prospective observational data from 17,635 subjects. Journal of the American College of Cardiology. 2014; 63: 636–646. https://doi.org/10.1016/j.jacc.2013.09.063

[9] Fernandes VRS, Polak JF, Cheng S, Rosen BD, Carvalho B, Nasir K, et al. Arterial Stiffness Is Associated With Regional Ventricular Systolic and Diastolic Dysfunction. Arteriosclerosis, Thrombosis, and Vascular Biology. 2008; 28: 194–201. https://doi.org/10.1161/ATVBAHA.107.156950

[10] Williams B, Mancia G, Spiering W, Agabiti Rosei E, Azizi M, Burnier M, et al. 2018 ESC/ESH Guidelines for the management of arterial hypertension. European Heart Journal. 2018; 39: 3021–3104. https://doi.org/10.1093/eurheartj/ehy339

[11] Park JB, Sharman JE, Li Y, Munakata M, Shirai K, Chen CH, et al. Expert Consensus on the Clinical Use of Pulse Wave Velocity in Asia. Pulse (Basel, Switzerland). 2022; 10: 1–18. https://doi.org/10.1159/000528208

[12] Wilkinson IB, MacCallum H, Flint L, Cockcroft JR, Newby DE, Webb DJ. The influence of heart rate on augmentation index and central arterial pressure in humans. The Journal of Physiology. 2000; 525 Pt 1: 263–270. https://doi.org/10.1111/j.1469-7793.2000.t01-1-00263.x

[13] Shirai K, Utino J, Otsuka K, Takata M. A novel blood pressure-independent arterial wall stiffness parameter; cardio-ankle vascular index (CAVI). Journal of Atherosclerosis and Thrombosis. 2006; 13: 101–107. https://doi.org/10.5551/jat.13.101

[14] Hou Z, Huang Y, Huang J, Lv Y, Zhao N, Lu H, et al. Can Pulse Arrival Time be Used for Cuffless Blood Pressure Estimation? A Clinical Study in ICU. Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual International Conference. 2024; 2024: 1–4. https://doi.org/10.1109/EMBC53108.2024.10781935

[15] Greenwood SA, Mangahis E, Castle EM, Wang J, Campbell J, Deshpande R, et al. Arterial stiffness is a predictor for acute kidney injury following coronary artery bypass graft surgery. Journal of Cardiothoracic Surgery. 2019; 14: 51. https://doi.org/10.1186/s13019-019-0873-3

[16] Hori D, Nomura Y, Nakano M, Akiyoshi K, Kimura N, Yamaguchi A. Relationship between endothelial function and vascular stiffness on lower limit of cerebral autoregulation in patients undergoing cardiovascular surgery. Artificial Organs. 2021; 45: 382–389. https://doi.org/10.1111/aor.13868

[17] Feola M. The influence of arterial stiffness in heart failure: a clinical review. Journal of Geriatric Cardiology: JGC. 2021; 18: 135–140. https://doi.org/10.11909/j.issn.1671-5411.2021.02.004

[18] Tanaka T, Asami M, Yahagi K, Ninomiya K, Okuno T, Horiuchi Y, et al. Prognostic impact of arterial stiffness following transcatheter aortic valve replacement. Journal of Cardiology. 2021; 78: 37–43. https://doi.org/10.1016/j.jjcc.2021.01.007

[19] Plunde O, Bäck M. Arterial Stiffness in Aortic Stenosis and the Impact of Aortic Valve Replacement. Vascular Health and Risk Management. 2022; 18: 117–122. https://doi.org/10.2147/VHRM.S358741

[20] Obata Y, Barodka V, Berkowitz DE, Gottschalk A, Hogue CW, Steppan J. Relationship Between the Ambulatory Arterial Stiff-

ness Index and the Lower Limit of Cerebral Autoregulation During Cardiac Surgery. Journal of the American Heart Association. 2018; 7: e007816. https://doi.org/10.1161/JAHA.117.007816

[21] Plunde O, Hupin D, Franco-Cereceda A, Bäck M. Cardio-ankle vascular index predicts postoperative atrial fibrillation after cardiac surgery. European Heart Journal Open. 2023; 3: oead042. https://doi.org/10.1093/ehjopen/oead042

[22] Tavolinejad H, Erten O, Maynard H, Chirinos JA. Prognostic Value of Cardio-Ankle Vascular Index for Cardiovascular and Kidney Outcomes: Systematic Review and Meta-Analysis. JACC. Advances. 2024; 3: 101019. https://doi.org/10.1016/j.jacadv.2024.101019

[23] Laurent S, Cockcroft J, Van Bortel L, Boutouyrie P, Giannattasio C, Hayoz D, et al. Expert consensus document on arterial stiffness: methodological issues and clinical applications. European Heart Journal. 2006; 27: 2588–2605. https://doi.org/10.1093/eurheartj/ehl254

[24] Chirinos JA, Sweitzer N. Ventricular-Arterial Coupling in Chronic Heart Failure. Cardiac Failure Review. 2017; 3: 12–18. https://doi.org/10.15420/cfr.2017:4:2

[25] Antonini-Canterin F, Carerj S, Di Bello V, Di Salvo G, La Carrubba S, Vriz O, et al. Arterial stiffness and ventricular stiffness: a couple of diseases or a coupling disease? A review from the cardiologist's point of view. European Journal of Echocardiography. 2009; 10: 36–43. https://doi.org/10.1093/ejechocard/jen236

[26] Franchi F, Baldini G, Mautone M, Taccone FS, Santis PD, Rocco A, et al. Evaluation of arterial stiffness in cardiac surgical patients using applanation tonometry. Annals of Cardiac Anaesthesia. 2020; 23: 302–308. https://doi.org/10.4103/aca.ACA_207_18

[27] Wang X, Long Y, He H, Shan G, Zhang R, Cui N, et al. Left ventricular-arterial coupling is associated with prolonged mechanical ventilation in severe post-cardiac surgery patients: an observational study. BMC Anesthesiology. 2018; 18: 184. https://doi.org/10.1186/s12871-018-0649-7

[28] Kwon Y, Stafford PL, Enfield K, Mazimba S, Baruch MC. Continuous Noninvasive Blood Pressure Monitoring of Beat-By-Beat Blood Pressure and Heart Rate Using Caretaker Compared With Invasive Arterial Catheter in the Intensive Care Unit. Journal of Cardiothoracic and Vascular Anesthesia. 2022; 36: 2012–2021. https://doi.org/10.1053/j.jvca.2021.09.042

[29] Sigala E, Terentes-Printzios D, Gardikioti V, Baikoussis NG, Koumallos N, Katsaros A, et al. The Effect of Surgical Aortic Valve Replacement on Arterial Stiffness: Does the Valve Type Matter? Journal of Personalized Medicine. 2024; 14: 509. https://doi.org/10.3390/jpm14050509

[30] Miki Y, Tanaka A, Tokuda Y, Tobe A, Shirai Y, Yuhara S, et al. Clinical implications of the cardio-ankle vascular index before and after transcatheter aortic valve implantation. Journal of Cardiovascular Medicine (Hagerstown, Md.). 2023; 24: 302–307. https://doi.org/10.2459/JCM.0000000000001456

[31] Takahashi K, Yamamoto T, Shirai K. Reasons for the Decline of Cardio-Ankle Vascular Index (CAVI) in Aortic Valve Stenosis (AVS). Vascular Health and Risk Management. 2022; 18: 887–888. https://doi.org/10.2147/VHRM.S399737

[32] Hajjar L, Melo R, Galas F, Sundin M, Gullo A, Auler JJ. Intraoperative optimization of hemodynamic parameters is associated with a better outcome after cardiac surgery. Critical Care. 2008; 12: 260. https://doi.org/10.1186/cc6481

[33] Kepler T, Kuusik K, Lepner U, Starkopf J, Zilmer M, Eha J, et al. The Effect of Remote Ischaemic Preconditioning on Arterial Stiffness in Patients Undergoing Vascular Surgery: A Randomised Clinical Trial. European Journal of Vascular and Endovascular Surgery: the Official Journal of the European Society for Vascular Surgery. 2019; 57: 868–875. https://doi.org/10.1016/j.ejvs.2018.12.002

[34] Nadim MK, Forni LG, Bihorac A, Hobson C, Koyner JL, Shaw A, et al. Cardiac and Vascular Surgery-Associated Acute Kidney Injury: The 20th International Consensus Conference of the ADQI (Acute Disease Quality Initiative) Group. Journal of the American Heart Association. 2018; 7: e008834. https://doi.org/10.1161/JAHA.118.008834

[35] Oh CS, Park S, Wan Hong S, Kang WS, Yoon TG, Kim SH. Postoperative Delirium in Patients Undergoing Off-Pump Coronary Artery Bypass Grafting According to the Anesthetic Agent: A Retrospective Study. Journal of Cardiothoracic and Vascular Anesthesia. 2017; 31: 1988–1995. https://doi.org/10.1053/j.jvca.2017.02.047

[36] Heo GY, Koh HB, Kim HW, Park JT, Yoo TH, Kang SW, et al. Glycemic Control and Adverse Clinical Outcomes in Patients with Chronic Kidney Disease and Type 2 Diabetes Mellitus: Results from KNOW-CKD. Diabetes & Metabolism Journal. 2023; 47: 535–546. https://doi.org/10.4093/dmj.2022.0112

[37] Müller J, Taebling M, Oberhoffer R. Remote Ischemic Preconditioning Has No Short Term Effect on Blood Pressure, Heart Rate, and Arterial Stiffness in Healthy Young Adults. Frontiers in Physiology. 2019; 10: 1094. https://doi.org/10.3389/fphys.2019.01094

[38] Hori D, Yamamoto T, Kakiuchi T, Yamaguchi A. Preoperative vascular dysfunction is associated with acute kidney injury after cardiac surgery. Journal of Thoracic Disease. 2024; 16: 8271–8279. https://doi.org/10.21037/jtd-24-1291

[39] Safar ME, London GM, Plante GE. Arterial stiffness and kidney function. Hypertension (Dallas, Tex.: 1979). 2004; 43: 163–168. https://doi.org/10.1161/01.HYP.0000114571.75762.b0

[40] Tiefenbacher CP, Friedrich S, Bleeke T, Vahl C, Chen X, Niroomand F. ACE inhibitors and statins acutely improve endothelial dysfunction of human coronary arterioles. American Journal of Physiology. Heart and Circulatory Physiology. 2004; 286: H1425–H1432. https://doi.org/10.1152/ajpheart.00783.2003

[41] Asmar R. Effects of treatment on arterial stiffness and central blood pressure–points to consider. Journal of Clinical Hypertension (Greenwich, Conn.). 2015; 17: 105–106. https://doi.org/10.1111/jch.12477

[42] Godwin R, Melvin RL, Berkowitz DE, Gosling AF. Measurement of Pulse Arrival Time and Arterial Stiffness in Patients Undergoing Cardiac Surgery. Journal of Cardiothoracic and Vascular Anesthesia. 2024; 38: 2493–2495. https://doi.org/10.1053/j.jvca.2024.05.030

[43] ClinicalTrials.gov. Arterial Stiffness and Hemodynamics in Cardiac Surgery. Identifier: NCT06911593. 2024. Available at: https://clinicaltrials.gov/study/NCT06911593 (Accessed: 4 December 2025).