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REVIEW ARTICLE

Opportunities to Improve Health Economic Outcomes in Coronary Artery Disease: A Review of Care Pathways in the United States Healthcare System

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ABSTRACT

Background: Despite medical advances, coronary artery disease remains the leading cause of death worldwide. Evidence suggests that current uptake and efficacy of strategies in coronary care are suboptimal. This review aimed to investigate key areas for improvements in coronary care in the United States, and to estimate the potential health gains if existing strategies were improved.

Methods: A targeted literature review of the acute and chronic coronary artery disease care pathways was conducted to identify areas where health outcomes could be improved in the United States if uptake or efficacy of existing strategies were optimal. Using hypothetical scenarios of maximally improved efficacy or uptake from published literature and health impact modeling, we calculated potential additional lives saved and potential reductions in direct medical costs, using Medicare rates as proxy, if improvements were realized.

Results: We identified the following areas where improvements in uptake or efficacy of existing strategies could positively impact coronary artery disease outcomes in the United States: primary prevention, early detection, efficient diagnosis, reducing time to reperfusion, and secondary prevention. Improvements in primary and secondary coronary artery disease prevention have the potential to reduce annual direct medical costs by approximately $17 billion USD and $5 billion USD, respectively. Further, if the efficacy of existing preventive strategies was improved to 80%, then 102,000 (primary prevention) and 32,000 (secondary prevention) lives could be saved annually. Improvements in early detection, more efficient diagnosis, and reducing time to reperfusion could also substantially increase lives saved by increasing the uptake and efficacy of timelier percutaneous interventions, and potentially reduce annual direct medical costs by $1 billion USD.

Conclusions: Improvements in primary prevention offer the greatest potential for lives saved and medical costs avoided. Future innovations should focus on advancing existing primary preventive strategies, while simultaneously driving innovation towards developing effective novel strategies in each of the key areas for improvement.

Non-Standard Abbreviations and Acronyms

ACC	American College of Cardiology
AHA	American Heart Association
AI	Artificial intelligence
AMI	Acute myocardial infarction
CAD	Coronary artery disease
CVD	Cardiovascular disease
ECG	Electrocardiography
FFR_{CT}	Fractional flow reserve-computed tomography
HCP	Healthcare professionals
HRQoL	Health-related quality of life
Hs-cTnI	High sensitivity troponin I
MACE	Major adverse cardiac event
ML	Machine learning
PCI	Percutaneous intervention
POC	Point-of-care
RRR	Relative risk reduction
SPM	Secondary prevention medicines
STEMI	ST-elevated myocardial infarction
cTnI	Troponin-1
UA	Unstable angina

1. Introduction

Coronary artery disease (CAD) is the most common type of cardiovascular disease (CVD), representing just over a third of global CVD burden.[1,2] The majority of acute myocardial infarctions (AMIs) are caused by CAD, with an incidence of approximately 605,000 new and 200,000 recurrent attacks per year.[3] In 2020, approximately 380,000 people died from CAD in the US alone.[1] Key risk factors for developing this disease include hypertension, obesity, and smoking, among others, with almost half of the US population living with at least one of these risk factors.[4]

From a cost perspective, CAD places a considerable demand on the healthcare system due to potentially expensive and invasive treatments associated with long-term management of the disease. Indeed, annual US healthcare costs for CVD were estimated at approximately $229 billion USD in both 2017 and 2018,[1] while first and recurrent AMIs have been estimated to cost $35,000 and $32,000 USD, respectively, in 90-day post-event direct medical costs.[5] Aside from cost, the daily challenges of living with CAD may also be associated with impaired health-related quality of life (HRQoL) among patients.[6]

Despite this obvious burden, CVD mortality rates have decreased in the past few decades,[7,8] though CVD remains the leading cause of death in the US.[1] Furthermore, the decline in mortality observed over recent years is now beginning to dissipate,[9] indicating the need for urgent intervention.

Several European studies have used the IMPACT-SEC health impact model to determine what proportion of mortality decline in CAD over a pre-defined period can be attributed to advances in medical treatment or to improvements in population-wide cardiovascular risk.[10-13] Findings demonstrated that the use of evidence-based treatments for acute and secondary prevention played a substantial role in reducing CAD mortality over the time frames studied; however, uptake of existing strategies may not be optimal.[10-13] Furthermore, the need for more effective population-wide strategies to mitigate the effects of adverse trends in certain persistent cardiovascular risk factors, such as smoking and obesity, was also highlighted.[10-13]

It is clear that, despite progress, more needs to be done to continue to decrease incidence and mortality rates in CAD, improve HRQoL for patients, and reduce CAD-associated healthcare costs. To direct innovation towards providing meaningful impact on health outcomes, it is necessary to firstly understand the current constraints faced by patients and healthcare professional (HCPs) in the management and treatment of CAD.
The aim of this review was to investigate the key areas for health economic improvements in CAD care pathways in the US healthcare system, and to estimate the potential health gains if uptake or effectiveness of existing strategies were to be improved.

2. Methods

A targeted literature review of the acute and chronic CAD care pathways was conducted to identify key areas where health outcomes could be improved in the US healthcare system if either uptake or efficacy of existing strategies were optimized.

We conducted a prospective analysis to calculate the potential maximum health gains (lives saved or direct medical costs avoided) based on hypothetical scenarios representing optimal uptake or efficacy of existing strategies in each of these key areas in US CAD care pathways (**Tables 1 and 2**). Previous studies retrospectively analyzed the effects of clinical interventions on CAD outcomes outside the US healthcare system.[10-13]

Table 1: Calculations on health outcomes.

Health impact measured	Calculation used
Current lives saved or extended	*Patient numbers × **treatment uptake** × **relative mortality reduction** × 1 year mortality rate before introduction of treatment*
Scenarios on improving uptake Additional lives saved	*((Maximum uptake of intervention − current uptake) ÷ current uptake of intervention) × number of lives saved with intervention under current uptake and current efficacy*
Scenarios on improving efficacy Additional lives saved	*((Maximum relative mortality rate of intervention – current relative mortality rate of intervention) ÷ current relative mortality rate of intervention) × number of lives saved with intervention under current uptake and current efficacy*
Reduction of economic waste Medical costs avoided*	*Number of redundant interventions × cost per intervention*†

*Based on costs for treatment or diagnostics; †Using Medicare rates as proxy. Using evidence from previous literature, these formulae were used to calculate potential additional lives saved and potential reductions in healthcare costs if uptake or efficacy of existing strategies were optimal in primary prevention, detection of early warning signs, efficient diagnosis, reducing time to reperfusion, and secondary prevention. Numerical data for these calculations is given in Table 3.

Table 2. Estimates of current and maximum uptake and efficacy of existing strategies in the CAD care pathways.

	Current relative efficacy in reducing mortality	Current uptake	Maximum potential relative efficacy in reducing mortality	Maximum potential uptake
Primary CAD prevention				
Efficacy	35%*	-	80%†	-
Uptake	-	30%*	-	100%†
PCI				
Efficacy	32%*	-	66%‡	-
Uptake	-	41%*	-	82%‡
Secondary CAD prevention				
Efficacy	26%*	-	80%†	-
Uptake	-	40%*	-	100%†

*Estimates of current efficacy and uptake of existing strategies were taken from previous health impact modeling and published literature;[10-13,20-23,29,33] †Proposed maximum values for primary and secondary preventions are taken from our estimates of best-case scenarios; ‡Proposed maximum values for PCI are based on calculations using evidence from previous literature.[3,12,29,30]
CAD, coronary artery disease; PCI, percutaneous intervention.

The Health Impact Model[14] was used as a validated analytical framework to include key determinants (opportunity areas) impacting 1-year mortality in CAD. The economic impacts of increased uptake or efficacy were extrapolated from the current evidence base. Studies were selected for further review on the premise of associated healthcare costs and resource utilization, as well as mortality, based on the number of deaths prevented or delayed. Medicare payment rates from 2021 were used as proxy to estimate potential reductions in direct medical costs. No adjustments were made for inflation. We did not calculate loss of income or other societal costs associated with CAD. Calculations utilized both generalized CVD data, as well as AMI-related data, from worldwide sources and from published studies using health impact modeling,[10-13] depending upon context and availability of data.

3. Results

3.1 IDENTIFICATION OF AREAS FOR IMPROVEMENT

From the literature, we identified the following areas where there is the greatest opportunity to improve CAD healthcare outcomes in the US:

- Primary prevention
- Detection of early warning signs
- Efficient diagnosis
- Reducing time to reperfusion
- Secondary prevention

For the context of this analysis, primary and secondary preventive strategies included lifestyle modifications, pharmacotherapy (i.e., statins, anti-hypertensives), rehabilitation, and revascularization. Potential health outcomes were calculated individually for primary and secondary prevention using evidence on "overall" prevention to represent the theoretical best-case scenario for either primary or secondary prevention.

The calculations around better detection of acute events, more efficient diagnosis, and reduced time to reperfusion relate solely to improved uptake or effectiveness of percutaneous coronary intervention (PCI), with the rationale that improvements in those areas could ensure that more patients (better uptake) undergo PCI at the clinically optimal time (improved efficacy).

3.2 PRIMARY PREVENTION

Approximately 80% of all major adverse cardiac events (MACE; usually defined as fatal or non-fatal AMI, or acute stroke) are preventable through lifestyle modifications and commitment to continual education as guidelines and recommendations evolve.[15] Primary prevention focuses on early intervention to mitigate risk before the onset of CAD or the incidence of a MACE. For high-risk patients or those already living with CAD, adherence to pharmacotherapy, such as statins or beta blockers, in combination with healthy lifestyle choices, can play a crucial role in halting disease progression.[2,16-18] Therefore, as well as being more cost-effective to implement,[19] primary preventive strategies may also assert a more significant impact on cardiovascular health, compared with treating or controlling CAD once it is present or has already begun causing symptoms. Based on published evidence in the literature and previous health impact modeling data, we estimated the current relative effectiveness and uptake of primary preventive strategies to be suboptimal, at 35%,[10,12,13,20-22] and 30%[20,23] respectively, indicating the need for improvements in both areas.

Approximately half of all patients under 55 years of age who were hospitalized for an AMI were unaware that they were classified as high-risk for CAD.[24] More accurate identification of at-risk individuals would improve the uptake of primary preventive strategies and allow for more timely delivery of preventive treatments, therefore improving their efficacy.

The efficacy of any primary preventive strategy hinges upon the willingness of individuals to adhere to it. In the case of statin therapy, adherence is often low, perhaps due to undesirable side-effects often associated with high-dose regimes,[25-27] among other reasons. Poor adherence to statins as a primary preventive strategy has also been associated with adverse cardiovascular outcomes.[28] Therefore, improvements in adherence to maximize uptake of primary preventive strategies could positively impact health outcomes in CAD.

3.2.1 Potential health gains from improving primary preventive strategies

Based on previous reports of the number of first-time AMIs being 605,000 per year in the US,[3] and a 1-year mortality rate of 0.21,[12] we calculated the theoretical total annual 1-year mortality after first AMI as 127,000 deaths. Given that 80% of all MACE are thought to be preventable,[15] we predicted that 102,000 of 127,000 deaths could potentially be avoided each year through primary prevention. We calculated that by solely maximizing effectiveness of current primary preventive strategies to 80% at current uptake (30%), an additional 19,695 lives could be saved (35,014 total lives potentially saved through effective primary prevention) (**Table 3**). By maximizing only the uptake of existing primary preventive strategies to 100% at current efficacy (35%), an additional 35,743 lives could theoretically be saved (51,062 total lives potentially saved through improved uptake of primary prevention) (**Table 3**).

The average direct medical cost after first AMI was previously estimated at ~$35,000 USD,[5] therefore we calculated that preventing 80% of first-time AMIs (605,000) from the known high-risk group (50% of the total risk population[24]) could theoretically reduce medical costs for treatment or diagnostics by $8.5 billion USD annually. Preventing 80% of AMIs from all risk groups (100% of the risk population) could potentially double this saving to $17 billion USD annually (**Table 3**). Thus, it is evident that increasing the uptake and/or efficacy of existing primary preventive strategies represents a critical opportunity to improve CAD care in terms of the potential for lives saved and reduced medical costs.

Table 3. Summary of key findings on potential lives saved and direct medical costs avoided by improving current strategies.

	Potential lives saved			Direct medical costs avoided§
	Current lives saved*	**Additional lives saved†**	**Total lives saved‡**	**Potential annual saving ($ USD)**
Primary CAD prevention	15,319	-	-	$17 billion
Improving efficacy	-	19,695	35,014	
Improving uptake	-	35,743	51,062	
PCI	25,084	-	-	$1 billion
Improving efficacy	-	26,652	51,735	
Improving uptake	-	25,084	50,168	
Secondary CAD prevention	4800	-	-	$5.1 billion
Improving efficacy	-	9969	14,769	
Improving uptake	-	7200	12,000	

Calculations were worked out using estimates of maximum uptake or maximum relative efficacy in reducing mortality shown in **Table 2**, and using the formulae described in **Table 1**. *Lives saved based on current combined uptake **and** efficacy of intervention; †Additional lives saved through intervention over and above current lives saved, if current uptake **or** efficacy were at maximum; ‡Total lives saved through intervention if current uptake **or** efficacy were at maximum (Current lives saved + additional lives saved); §Direct medical costs relate solely to direct costs associated with CAD treatment; they do not take into consideration additional reductions in societal costs, such as loss of earnings.

3.3 ACUTE OR PREVENTIVE PERCUTANEOUS CORONARY INTERVENTION

Estimates from the literature suggest that the relative efficacy of PCI in reducing mortality is just 32%.[10] We estimated the current uptake of acute PCI at 41%, based on 805,000 patients suffering from AMI each year[3] and just 340,000 acute PCI procedures (ST-elevated myocardial infarction [STEMI] + non-STEMI devices) performed in 2022.[29] These sub-optimal figures may be partially explained by the observation that the effectiveness of PCI in preventing mortality following a MACE is significantly lower in patients with a door-to-balloon time over 90 minutes,[24] suggesting that many patients may not be receiving treatment within the critical window to receive maximum clinical benefits. Lack of access to care, lack of insurance, or reluctance to seek care may also factor in suboptimal uptake and efficacy of acute PCI. Conversely, preventive PCI in an elective setting has the potential to improve patient outcomes and reduce future medical costs by decreasing the likelihood of an adverse event. We suggest that better detection of early warning signs of acute events, more efficient diagnosis, and reduced time to perfusion are all means of improving the uptake and effectiveness of both acute and preventive PCI to maximize health gains.

3.3.1 Detection of early warning signs of acute cardiac events

In approximately 50% of deaths caused by plausible or uncertain AMIs, patients, such as those with silent AMIs or those living alone, die outside of the hospital without receiving acute in-hospital treatment for the event.[30] Timely recognition of an acute cardiac event through accurate identification of symptoms and correlation with clinical signs to allow adequate time to seek appropriate medical attention within the optimal therapeutic window is key for patients and HCPs. However, a report from the American Heart Association (AHA) indicated that almost half of people living in the US were unaware of five common signs of an AMI, with even less symptom awareness in males and among Black, Hispanic, and Asian individuals.[24] Early recognition of symptoms and correct escalation by HCPs is key to ensuring treatment is given within the optimum therapeutic window in the event of acute PCI, and before the occurrence of MACE in individuals who may be eligible for preventive PCI in an elective setting.

3.3.2 Efficient diagnosis

Typically, electrocardiography (ECG) is used as a first-line tool in the diagnosis of CAD, while troponin-1 (cTnI) is the preferred biomarker assay for non-invasive assessment of early myocardial damage associated with AMI.[31] Thereafter, angiography is routinely used as a follow-up diagnostic tool to confirm initial observations. However, overuse of angiography in CAD diagnostics without initial non-invasive testing[32] could lead to increased healthcare costs. For example, an angiography costs around $2,900 USD per patient (based on Medicare rates), but approximately 40% of angiography results reveal no evidence of obstructive CAD.[33] The annual cost of angiograph procedures is estimated at approximately $3 billion USD, based on 1,200,000 procedures performed in 2014 alone.[24] Thus, overuse of angiography where CAD is not the underlying issue could be potentially costly. Additionally, there are attendant risks and potential complications to consider, such as bleeding risks, anesthesia complications, and acute kidney injury from the use of contrast material.

We calculated that a 40% reduction in invasive diagnostic angiographic procedures (based on current uptake of angiographs where CAD is not the underlying cause)[33] could potentially save up to $1.4 billion USD annually in direct medical costs. Optimal use of non-invasive first-line diagnostic testing in non-high-risk patients could help to prevent overuse of angiography, leading to improved outcomes from both an economic and a health perspective.

3.3.3 Reducing time to reperfusion

Despite the timing for PCI being a critical factor in its success rate, almost half of patients were shown to arrive at hospital more than 2 hours after the onset of AMI symptoms and outside of the optimal therapeutic window,[24] potentially reducing the effectiveness of a subsequent acute PCI. Further, it has been reported that females experience longer door-to-balloon times and lower rates of guideline-directed medical therapy than males.[24] The reasons for this are unclear, though greater symptom complexity and biases may be behind delays in door-to-balloon times in women with AMI;[34] while lack of access to care may be a critical factor in overall delays. Reducing time to reperfusion through better awareness of early warning signs and more efficient diagnosis, particularly in response to variable symptomatology, could improve effectiveness of PCI by maximizing the number of patients undergoing elective procedures before a MACE, and within the recommended 90-minute door-to-balloon time for an acute PCI.

3.3.4 Potential health gains from improving uptake or effectiveness of percutaneous coronary intervention

Using our estimation of the current uptake of PCI as 41%,[3,29] we theorized that if acute PCI had been available for the estimated 50% of AMI patients dying outside of the hospital without receiving acute in-hospital treatment,[30] the maximum potential uptake of PCI could be doubled to 82%. Therefore, we predicted that an additional 25,084 lives could be saved annually (50,168 total lives saved through PCI) and 19% of potential AMI deaths could be avoided, based on a current relative risk reduction (RRR) of 32%[10] (**Table 3**).

Based on prior health-impact data reporting 1-year mortality from unstable angina as 66% lower than for AMI,[12] we also predicted that the relative maximum efficacy of PCI could theoretically be increased to 66% through early intervention with PCI before an acute event. By improving the relative maximum effectiveness of PCI to 66% through performing timelier preventive PCIs in an elective setting before any irreversible damage to the heart, we calculated that an additional 26,652 lives could be saved annually (51,735 total lives saved through PCI) (**Table 3**).

From a cost perspective, using Medicare rates as a proxy, preventive PCIs (PCI unstable angina [UA]: $10,000 USD) are less expensive than acute PCIs (PCI AMI inpatient: $20,100 USD); highlighting the potential to reduce healthcare costs by increasing the uptake of preventive PCI in an elective setting. We therefore calculated the potential saving from performing a preventive PCI versus an acute PCI to be $10,100 USD per procedure. Using this potential saving alongside previous reports of 125,000 acute PCIs being performed in the US in 2022 (predicted for STEMI devices only),[29] we estimated that an 80% reduction in acute PCIs in favor of timelier preventive PCI procedures could theoretically save approximately $1 billion USD per year in direct medical costs.

3.4 SECONDARY PREVENTIVE STRATEGIES

Approximately 200,000 out of 805,000 AMIs in the US each year are recurrent attacks,[3] with mortality increasing among patients with inadequately controlled risk factors.[24,35,36] The aim of secondary prevention is to prevent the recurrence of MACE and to reduce morbidity and mortality in individuals who have experienced a prior event, or among those who are considered very-high-risk due to prior coronary surgical procedures, through a combination of education, lifestyle modifications, pharmacotherapy, revascularization, and rehabilitation. As with primary prevention, the success of secondary preventive strategies is largely dependent upon the willingness of individuals to adhere to prescribed treatment regimens and lifestyle modifications. In addition, HCPs must be able to correctly identify individuals who may benefit from secondary prevention and then provide information, appropriate treatment, and continual support to enable patients to adhere to their treatment plan.

Cardiac rehabilitation has been shown to reduce cardiac risk and improve the QoL of patients after an acute event.[37,38] As such, the American College of Cardiology (ACC) and the AHA strongly recommend cardiac rehabilitation as a secondary preventive treatment following AMI, stable and unstable angina, or revascularization.[39,40] However, studies have shown that despite the endorsement from the ACC and the AHA, as well as the claim that 80% of all cardiac events are preventable,[15] referral to cardiac rehabilitation for secondary prevention after PCI remains relatively poor at around 48%, despite >90% of patients being eligible for referral.[41] Furthermore, fewer than 50% of patients who were referred participated in cardiac rehabilitation within the first 6 months after AMI,[42] suggesting a lack of willingness among patients to comply with this kind of secondary preventive measure, or a lack of access to this service. Poor compliance is also evident with use of secondary prevention medicines (SPM), with reports of up to 50% of patients with CAD said to be non-adherent to their SPM regime.[43]

Using prior evidence from health impact modeling, we estimated the current relative uptake of existing secondary preventive strategies at approximately 40%,[12] while their current efficacy in reducing mortality was estimated at 26%,[10,12,13] highlighting the need for improvement.

3.4.1 Potential health gains from improving secondary preventive strategies

Based on previous reports of the number of first-time AMIs being 200,000 per year in the US,[3] and a 1-year mortality rate of 0.21 from prior health-modeling data,[12] we calculated the theoretical total annual 1-year mortality after recurrent AMI as 42,000 deaths. Since 80% of all MACE are preventable,[15] we calculated that a maximum of 32,000 deaths per year could potentially be prevented through secondary prevention. By solely improving relative efficacy of secondary preventive strategies to 80%, 7% of AMI deaths could be avoided and 9969 additional lives could be saved (14,769 total lives potentially saved through effective secondary prevention) (**Table 3**). Improving only the uptake of secondary preventive strategies to 100% could avoid 5% of AMI deaths and save an additional 7200 lives (12,000 total lives potentially saved through uptake of secondary prevention) (**Table 3**).

Furthermore, assuming the cost of a recurrent AMI at $32,000 USD,[5] we calculated that an 80% reduction[15] of 200,000 recurrent AMIs each year[3] through secondary preventive strategies could reduce direct medical costs by $5.1 billion USD annually (**Table 3**).

5. Discussion

Our analysis indicated that improving the uptake or effectiveness of primary preventive strategies could potentially have the greatest economic impact on saving lives and reducing costs by mitigating the risk of future illness and the need for potentially stressful, costly, and invasive medical procedures. We estimated that 102,000 lives could be saved each year if 80% of first-time AMIs were prevented, with a potential saving in direct annual healthcare costs of ~$17 billion USD. Similarly, an 80% reduction of recurrent AMIs through secondary prevention could theoretically save 32,000 lives each year and ~$5.1 billion USD in direct medical costs.

Increasing the detection of early warning signs, improving diagnosis, and reducing time to reperfusion in order to maximize the uptake and efficiency of preventive PCI or acute PCI performed within the optimal therapeutic window could also have a considerable impact on associated medical costs and health outcomes for patients. We predicted that increased efficacy or uptake of PCI could save an additional 26,652 or 25,084 lives per year, respectively. Furthermore, the use of timelier and more cost-effective preventive PCIs performed in an elective setting before the onset of a MACE, and prior to the need for a more expensive acute PCI, could potentially save ~$1 billion USD annually in direct medical costs.

Significant cost reductions could also be achieved by providing more efficient, personalized diagnostics in CAD and minimizing the overuse of invasive diagnostics, such as angiographs, in cases where CAD is not the underlying cause. We calculated that these improvements could potentially save ~$1.4 billion USD annually in direct medical costs.

Each of these areas for improvement represents its own unique opportunity to improve care for CAD patients, but they are not independent from one another, and improvements in one area may positively impact upon key areas further down the care pathway. Successful primary prevention, for example, is critical in impacting all other aspects of CAD management by reducing the number of individuals living with CAD in the first instance.

To the best of our knowledge, our analysis presents a unique insight on prospective health impact modeling in CAD care in the US. It should be noted, however, that these calculations are theoretical, based upon available cost and health outcomes data in the literature. Therefore, not all data derived from previous health-impact modeling are US-specific. Nonetheless, they serve to illustrate the maximum potential for improvements in the aforementioned key areas of the CAD care pathway in saving lives and reducing healthcare costs to create a better healthcare experience for patients and HCPs in the US. Furthermore, our calculations focus solely on reducing waste through the avoidance of direct medical costs associated with the treatment of CAD. We did not calculate additional savings through the avoidance of societal costs, or indeed, potential additional costs accrued through patients ultimately living longer and increasing their overall healthcare utilization. In a real-world setting, these would be important considerations when evaluating overall economic impact; however, this was not the scope of our analysis.

While more needs to be done to improve healthcare outcomes in CAD, a number of key innovations are currently in use or under development that could improve effectiveness or uptake of existing strategies in each of the key areas for improvement.

For example, mobile digital technology offers a unique opportunity to provide non-invasive, round-the-clock support and information on positive lifestyle practices for primary and secondary prevention of CAD, in a cost-effective way that can fit into a patients' daily life and improve access to previously limited services, such as cardiac rehabilitation.[44,45] Mobile apps can also be used to provide daily check-ins and prompts to support adherence to healthy lifestyle practices and prescribed pharmacotherapy, with initial studies reporting improved adherence to guideline-recommended medications among patients using a mobile app.[44,45] Thus, growing evidence suggests that teleconsultations, SMS systems, smartphone apps and remote wearable devices may help to reduce cardiac risk factors,[46] indicating their potential to improve the efficacy of existing preventive strategies. Large-scale clinical trials and real-world evidence are needed to verify these initial findings, and to demonstrate wide-spread feasibility and acceptance among users in a real-world setting.

With regards to improving early detection of acute cardiac events, several studies have reported significant reductions in door-to-balloon time and an increase in timelier PCI after implementing tele-ECG in primary care as a means of accurately triaging patients outside of a hospital setting, indicating its potential as a cost-effective means to improve CAD outcomes by reducing time to reperfusion.[47-49]

From a diagnostic perspective, broader, risk-adjusted pathways with safer and more time- and cost-efficient means of diagnosis would benefit the care pathway both in terms of cost and by minimizing potential harm for patients. High-sensitivity biomarker assays offer a unique opportunity to support more efficient diagnosis leading to timelier treatment by creating accurate, rapid, and cost-effective tools, which can be used by clinicians at point of care (POC), as opposed to in a laboratory setting. High sensitivity cTnI (hs-cTnI) POC assays can offer results in <20 minutes for rule-in/rule-out testing of AMI, with reports of comparable accuracy with laboratory-based assays when using stored plasma;[50] though these initial findings require further validation in large-scale trials using whole blood.[50]

Artificial intelligence (AI) and machine learning (ML) are also useful tools in the quest to improve CAD diagnostics, offering the ability to combine and compute POC biomarker data with data on clinical history, pre-existing risk factors, and biomarker trends. Furthermore, they can be used to more accurately predict risk and identify patients who may require further diagnostic testing[51] as a means of CAD prevention. Both tools can also be used in the interpretation of enhanced imaging techniques, such as with fractional flow reserve-computed tomography (FFR_{CT}), where computational fluid dynamics are combined with coronary CT datasets to evaluate coronary artery stenosis non-invasively. As such, AI and ML offer the advantage of being able to rapidly compute data from multiple sources, therefore reducing processing time and leading to quicker treatment and potentially better outcomes for patients.[51]

6. Conclusion

Improving the uptake and/or efficacy of existing strategies in primary prevention, in particular, offers the greatest opportunity to significantly impact CAD care in the US through lives saved and direct medical costs avoided. Continued development and refinement of existing and emerging technologies for prevention, diagnosis, and management of CAD to ensure accuracy and cost-effectiveness in a real-world setting is fundamental to improving economic health outcomes in CAD care in the US.

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Author Contributions
All authors fulfilled the ICMJE criteria for authorship by contributing to the preparation of this manuscript and by providing approval of the final version. All authors agree to take responsibility for the content of this manuscript. SH, JF, AK, RJP, and PV were involved in the concept and design of this analysis; BDG was involved in concept and design, and data analysis and interpretation; and MH was involved in concept and design, data acquisition, and data analysis and interpretation.

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