



E-Cigarette Use and the Risk of Myocardial Infarction in Adults: A Systematic Review and Meta-Analysis

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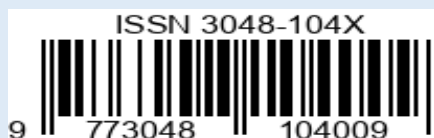
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ABSTRACT

Introduction: The proliferation of electronic cigarettes (e-cigarettes) has sparked a global debate regarding their cardiovascular safety, particularly their association with myocardial infarction (MI). While often perceived as a safer alternative to traditional cigarettes, their long-term effects on cardiac health are poorly understood, with existing evidence being conflicting and methodologically limited. This systematic review and meta-analysis aims to synthesize the available evidence on the relationship between e-cigarette use and the incidence of MI in adults.

Methods: Following PRISMA 2020 guidelines, a systematic search was conducted across PubMed, Semantic Scholar, Springer, and Google Scholar. Studies were included if they were observational (cohort, case-control, cross-sectional) or systematic

reviews examining e-cigarette use in adults and reporting MI as an outcome. Data on study design, population characteristics, exposure details, and MI risk estimates were extracted. A random-effects model was used for the meta-analysis to calculate a summarized hazard ratio (HR).

Results: Thirty studies were included in the systematic review. The meta-analysis of four eligible studies revealed that e-cigarette use was associated with a statistically significant increase in MI risk (HR 1.66, 95% CI 1.22–2.25, $p < 0.05$). However, significant heterogeneity was detected ($I^2 = 93\%$). Dual use of e-cigarettes and traditional cigarettes conferred the highest risk (OR up to 4.62). Compared to traditional smoking, e-cigarette use was associated with reduced odds of MI (OR 0.61). Acute use of e-cigarettes consistently increased blood pressure and heart rate.

Conclusion: E-cigarette use is associated with a significantly increased risk of myocardial infarction, although the evidence is highly heterogeneous. Dual use presents the greatest danger, while switching completely from traditional cigarettes may offer a degree of harm reduction. The low certainty of the current evidence, largely from cross-sectional studies, highlights an urgent need for long-term prospective research.

Keywords: Electronic Cigarettes, Vaping, Myocardial Infarction, Cardiovascular Disease, Systematic Review

INTRODUCTION

The global health landscape has been significantly altered by the proliferation of electronic cigarettes, often referred to as Electronic Nicotine Delivery Systems (ENDS). Initially marketed as a potentially safer alternative to combustible tobacco and a tool for smoking cessation, their use has surged among various populations, including adults who are current or former smokers (Glasser et al., 2017). This rise in popularity is accompanied by a growing public health debate regarding their true impact, particularly on long-term health outcomes. While perceptions of reduced risk have driven adoption, the scientific community remains cautious, underscoring the need for robust evidence to understand the full spectrum of their physiological effects (Busch et al., 2016).

Central to this debate is the impact of e-cigarette use on cardiovascular health, a major cause of morbidity and mortality worldwide. Traditional cigarette smoking is a well-established and primary risk factor for a host of cardiovascular diseases, including myocardial infarction (MI). However, the cardiovascular profile of e-cigarettes is far less understood, creating a critical knowledge gap for both clinicians and consumers. The central question is whether these devices represent a genuine harm reduction tool or if they introduce a new, distinct set of risks to the cardiovascular system, a concern that has prompted numerous scientific investigations (Skotsimara et al., 2019; Kundu et al., 2025). Investigations into the acute cardiovascular effects of e-cigarettes have yielded mixed and often conflicting results. Several studies report that e-cigarette use triggers immediate, unfavorable hemodynamic changes, such as increases in blood pressure, heart rate, and arterial stiffness, that are comparable to the effects of traditional cigarettes. These findings suggest that, at least in the short term, e-cigarettes are not necessarily benign to the vascular system. Conversely, other research indicates that while e-cigarettes do cause acute increases in these same cardiovascular parameters, the magnitude of these effects is significantly less than that observed with combustible cigarettes, suggesting a potentially lower, though not absent, acute risk (Franzen et al., 2018; Garcia et al., 2020; Kennedy et al., 2019; Terentes-Printzios et al., 2018).

The potential association between e-cigarette use and the incidence of myocardial infarction is a paramount public health concern. Emerging evidence from some large-scale observational studies suggests a worrying link, with reports indicating that daily e-cigarette use is associated with increased odds of having had a myocardial infarction. This risk appears to be substantially higher for "dual users"—individuals who smoke both traditional cigarettes and vape. Some analyses have reported that the odds of MI for dual users are significantly higher than for those who have never used either product, highlighting a potentially synergistic and dangerous interaction (Hajat et al., 2021; Chen et al., 2024).

However, the existing body of evidence is fraught with significant methodological limitations that temper definitive conclusions. Much of the research relies on cross-sectional study designs, which capture data at a single point in time and cannot establish causality or determine whether e-cigarette use preceded the myocardial infarction. Furthermore, many studies depend on self-reported data for both e-cigarette use and MI diagnosis, introducing potential recall and reporting bias. A major confounding factor is the failure in some studies to adequately distinguish between exclusive e-cigarette users, former smokers who switched to vaping, and dual users, making it difficult to isolate the independent risk of e-cigarettes (Wasfi et al., 2022).

This confluence of conflicting findings and methodological weaknesses has resulted in a highly heterogeneous and uncertain evidence base. Systematic reviews attempting to synthesize the data have noted this inconsistency, with some concluding there is insufficient evidence to confirm an association between e-cigarette use and MI, and others rating the certainty of the existing evidence as "very low". This lack of consensus prevents the formulation of clear public health guidelines and leaves users, healthcare providers, and policymakers without a definitive understanding of the long-term cardiovascular risks associated with vaping (Banks et al., 2023; Wasfi et al., 2022).

Therefore, this systematic review and meta-analysis was conducted to address this critical gap in knowledge. The primary objective of this research is to systematically evaluate and synthesize the available evidence on the relationship between e-cigarette smoking and the incidence of myocardial infarction in adults. By pooling data from relevant observational studies, this analysis aims to derive a more precise and statistically robust estimate of the risk, considering different patterns of use such as exclusive vaping and dual use with combustible cigarettes.

To achieve this, the study strictly adheres to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor, transparency, and reliability. By comprehensively searching multiple databases, applying stringent eligibility criteria, and critically appraising the quality of included studies, this research seeks to provide a clear synthesis of the current state of knowledge. The findings are intended to clarify the association between e-cigarette use and myocardial infarction risk, thereby informing clinical practice, guiding future research, and helping to shape evidence-based public health policies regarding these widely used products.

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate relationship of e-cigarette smoking and incidence of myocardial infarction in adults.

Screening

We screened in papers that met these criteria:

- **Adult Population:** Does the study include only participants aged 18 years or older?
- **E-cigarette Exposure:** Is e-cigarette use examined as a primary exposure with clear documentation of usage patterns?
- **Myocardial Infarction Outcome:** Does the study report myocardial infarction as a primary or secondary outcome?
- **Study Design:** Is the study either an observational study (cohort, case-control, cross-sectional) or a systematic review/meta-analysis?
- **Exposure Distinction:** Can e-cigarette use effects be clearly distinguished from other forms of tobacco use in the study?
- **Study Methodology:** Is the study conducted in human subjects with group-level analysis (not a case report/series, animal study, or in-vitro study)?
- **Exposure Specificity:** Does the study examine e-cigarette use (either alone or in addition to conventional cigarettes) rather than only conventional cigarette smoking?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Data extraction

We asked a large language model to extract each data column below from each paper. We gave the model the extraction instructions shown below for each column.

- **Study Design:**

Identify the specific type of study design used. Look in the methods section for details about:

- Type of study (e.g., cohort, cross-sectional, case-control)
- Prospective or retrospective nature
- Observational or interventional If multiple design elements are present, list all. If unclear, note "design not clearly specified".

- **Participant Characteristics:**

Extract detailed information about study participants:

- Total number of participants
- Age range or mean age
- Gender distribution
- Smoking status categories (e.g., e-cigarette users, traditional smokers, non-smokers)
- Any specific inclusion/exclusion criteria Record numerical values with percentages or proportions where possible. If ranges are given, record both minimum and maximum values.

- **E-Cigarette Exposure Details:**

Capture specific details about e-cigarette use:

- Duration of e-cigarette use
- Frequency of use
- Type/brand of e-cigarettes (if specified)
- Concurrent use with traditional cigarettes (if applicable) If exact details are not provided, note "insufficient information". If multiple use patterns are reported, list all.

- **Myocardial Infarction Outcome Measurement:**

Extract specific details about MI outcome:

- Method of MI diagnosis/confirmation
- Total number of MI events
- Percentage or rate of MI events by group
- Time frame for MI event detection Record numerical values with confidence intervals or p-values if available. If multiple reporting methods exist, prioritize most precise measurement.

- **Statistical Analysis Results:**

Record key statistical findings related to MI risk:

- Odds Ratio (OR)
- Confidence Interval
- P-value
- Adjusted vs. unadjusted analysis Prioritize adjusted analyses if both are reported. If multiple

statistical approaches are used, list all significant results.

- **Risk of Bias Assessment:**

Evaluate study's methodological quality:

- Conflicts of interest disclosed
- Funding sources
- Potential sources of bias
- Quality assessment score (if provided) If no formal bias assessment is conducted, note "no formal bias assessment reported". Look for statements about potential limitations in discussion section.

Search Strategy

The keywords used for this research based PICO :

Element	Keyword 1	Keyword 2	Keyword 3	Keyword 4
Population (P)	Adults	Adult Population	Smokers	Adults Smokers
Intervention (I)	E-Cigarette Smoking	E-cigarette use	Vaping	Electronic nicotine delivery systems
Comparison (C)	Traditional smoking	Conventional cigarettes	Traditional cigarettes	Tobacco cigarettes
Outcome (O)	Myocardial Infarction	Cardiac Infarction	Myocardial Necrosis	Coronary Infarction

The Boolean MeSH keywords inputted on databases for this research are: ("*Adults*" OR "*Adult Population*" OR "*Smokers*" OR "*Adults Smokers*") AND ("*E-Cigarette Smoking*" OR "*E-cigarette use*" OR "*Vaping*" OR "*Electronic nicotine delivery systems*") AND ("*Traditional smoking*" OR "*Conventional cigarettes*" OR "*Traditional cigarettes*" OR "*Tobacco cigarettes*") AND ("*Myocardial Infarction*" OR "*Cardiac Infarction*" OR "*Myocardial Necrosis*" OR "*Coronary Infarction*")

Data retrieval

Abstracts and titles were screened to assess their eligibility, and only studies meeting the inclusion criteria were selected for further analysis. Literature that fulfilled all predefined criteria and directly related to the topic was included. Studies that did not meet these criteria were excluded. Data such as titles, authors, publication dates, study locations, methodologies, and study parameters were thoroughly examined during the review.

Quality Assessment and Data Synthesis

Each author independently assessed the titles and abstracts of the selected studies to identify those for further exploration. Articles that met the inclusion criteria underwent further evaluation. Final decisions on inclusion were based on the findings from this review process.

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	("Adults" OR "Adult Population" OR "Smokers" OR "Adults Smokers") AND ("E-Cigarette Smoking" OR "E-cigarette use" OR "Vaping" OR "Electronic nicotine delivery systems") AND ("Traditional smoking" OR "Conventional cigarettes" OR "Traditional cigarettes" OR "Tobacco cigarettes") AND ("Myocardial Infarction" OR "Cardiac Infarction" OR "Myocardial Necrosis" OR "Coronary Infarction")	8
Semantic Scholar	("Adults" OR "Adult Population" OR "Smokers" OR "Adults Smokers") AND ("E-Cigarette Smoking" OR "E-cigarette use" OR "Vaping" OR "Electronic nicotine delivery systems") AND ("Traditional smoking" OR "Conventional cigarettes" OR "Traditional cigarettes" OR "Tobacco cigarettes") AND ("Myocardial Infarction" OR "Cardiac Infarction" OR "Myocardial Necrosis" OR "Coronary Infarction")	253
Springer	("Adults" OR "Adult Population" OR "Smokers" OR "Adults Smokers") AND ("E-Cigarette Smoking" OR "E-cigarette use" OR "Vaping" OR "Electronic nicotine delivery systems") AND ("Traditional smoking" OR "Conventional cigarettes" OR "Traditional cigarettes" OR "Tobacco cigarettes") AND ("Myocardial Infarction" OR "Cardiac Infarction" OR "Myocardial Necrosis" OR "Coronary Infarction")	121
Google Scholar	("Adults" OR "Adult Population" OR "Smokers" OR "Adults Smokers") AND ("E-Cigarette Smoking" OR "E-cigarette use" OR "Vaping" OR "Electronic nicotine delivery systems") AND ("Traditional smoking" OR "Conventional cigarettes" OR "Traditional cigarettes" OR "Tobacco cigarettes") AND ("Myocardial Infarction" OR "Cardiac Infarction" OR "Myocardial Necrosis" OR "Coronary Infarction")	2,660

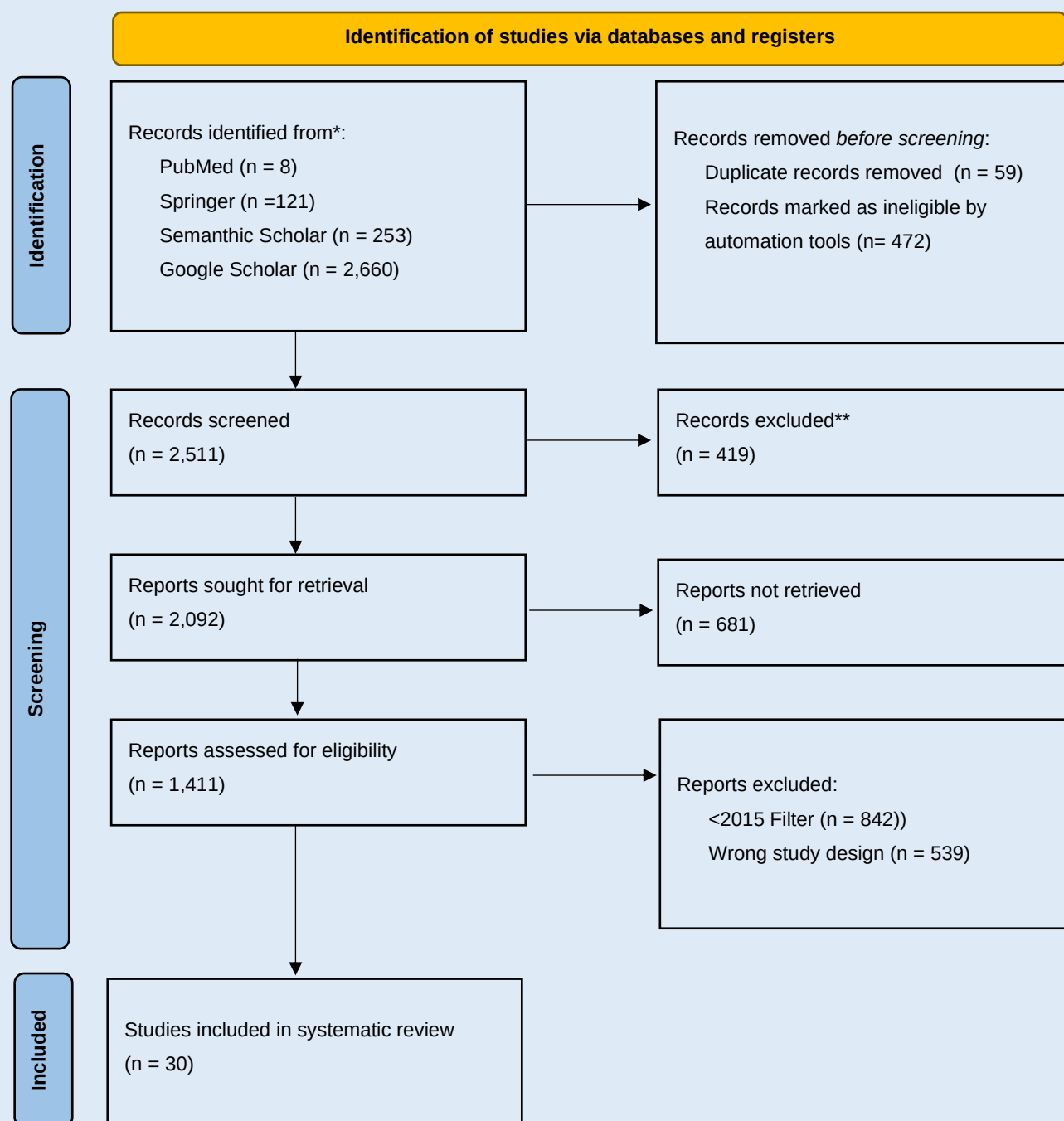


Figure 1. Article search flowchart

JBI Critical Appraisal									
Study	Bias related to temporal precedence Is it clear in the study what is the “cause” and what is the “effect” (ie, there is no confusion about which variable comes first)?	Bias related to selection and allocation Was there a control group?	Bias related to confounding factors Were participants included in any comparisons similar?	Bias related to administration of intervention/exposure Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Were there multiple measurements of the outcome, both pre and post the intervention/exposure?	Were the outcomes of participants included in any comparisons measured in the same way?	Were outcomes measured in a reliable way?	Bias related to participant retention Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Statistical conclusion validity Was appropriate statistical analysis used?
Busch et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Franzen et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
La Rosa et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Amato et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓

Damay et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Izquierdo-Condoy et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Hajat et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Magna et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Chen et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Wasfi et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Riley et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Klonizakis et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Kennedy et al., 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓
Kundu et al., 2025	✓	✓	✓	✗	✓	✗	✓	✓	✓
Antonopoulos et al., 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓
Harris and Foley, 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓

Sharma and Verma, 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Chapman et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Cheraghi et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Banks et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Bozier et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Glasser et al., 2017	✓	✓	✓	✗	✓	✗	✓	✓	✓
Garcia et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Goniewicz et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Sharma et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
Sharma et al., "E-Cigarettes and Myocardial Infarction" , 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Yacoub et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓

Skotsimara et al., 2019									
Vaz- Carneiro and Costa, 2015									
Terentes- Printzios et al., 2018									

Characteristics of Included Studies			
Study	Population Size	Study Duration	Primary Outcomes Measured
Busch et al., 2016	49	24 weeks post-acute coronary syndrome	E-cigarette use, myocardial infarction risk perception
Franzen et al., 2018	15	2 hours (acute)	Hemodynamic effects (blood pressure, heart rate, arterial stiffness)
La Rosa et al., 2023	1,810	5 days-24 months	Cardiovascular effects of e-cigarette substitution
Amato et al., 2020	No mention found	No mention found	Health effects of e-cigarettes
Damay et al., 2022	No mention found	1-4 months (human), 5 days-60 weeks (animal)	Vascular effects, myocardial infarction (in some studies)
Izquierdo-Condoy et al., 2024	No mention found	5 days-3.5 years	Direct health effects (including myocardial infarction)

Characteristics of Included Studies			
Study	Population Size	Study Duration	Primary Outcomes Measured
Hajat et al., 2021	37 studies	No mention found	Health impact of electronic nicotine delivery systems (including myocardial infarction)
Magna et al., 2024	No mention found	No mention found	Oxidative stress, atherosclerosis, cardiovascular disease
Chen et al., 2024	8,499,444	No mention found	Cardiovascular disease (including myocardial infarction)
Wasfi et al., 2022	No mention found	No mention found	Chronic health outcomes (including myocardial infarction)
Riley et al., 2016	Various (e.g., 1,355 in one study)	No mention found	Myocardial infarction, stroke, cardiovascular markets in women using e-cigarettes and hormonal contraception

Characteristics of Included Studies			
Study	Population Size	Study Duration	Primary Outcomes Measured
Klonizakis et al., 2022	248	3 months	Medium/long-term cardiovascular effects
Kennedy et al., 2019	24 human studies (10-408 per study)	No mention found	Cardiovascular effects (heart rate, blood pressure, endothelial function)
Kundu et al., 2025	63 studies	No mention found	Cardiovascular health effects (acute, short/medium, long-term)
Antonopoulos et al., 2019	441	No mention found	Cardiovascular effects (heart rate, blood pressure, endothelial function)
Harris and Foley, 2020	93 (injury cases)	No mention found	Cardiac stimulant effects, myocardial infarction risk, injuries

Characteristics of Included Studies			
Study	Population Size	Study Duration	Primary Outcomes Measured
Sharma and Verma, 2020	No mention found	No mention found	Health consequences of vaping (including myocardial infarction)
Chapman et al., 2020	No mention found	No mention found	Health effects of e-cigarettes
Cheraghi et al., 2024	370	Acute (minutes-hours)	Acute cardiovascular effects (pulse wave velocity, augmentation index, flow-mediated dilation, heart rate, blood pressure)
Banks et al., 2023	No mention found	No mention found	Health outcomes (including cardiovascular disease, myocardial infarction)
Bozier et al., 2020	No mention found	No mention found	Health effects of e-cigarettes

Characteristics of Included Studies			
Study	Population Size	Study Duration	Primary Outcomes Measured
Glasser et al., 2017	No mention found	No mention found	Electronic nicotine delivery systems health effects, use patterns
Garcia et al., 2020	19 studies (15-40 per study)	No mention found	Autonomic cardiovascular effects
Goniewicz et al., 2020	19,475-161,529 per study	Retrospective	Respiratory and cardiovascular outcomes (including myocardial infarction)
Sharma et al., 2022	585,306	No mention found	Myocardial infarction incidence
Sharma et al., "E-Cigarettes and Myocardial Infarction", 2024	585,306	No mention found	Myocardial infarction incidence

Characteristics of Included Studies			
Study	Population Size	Study Duration	Primary Outcomes Measured
Yacoub et al., 2024	20 studies (no mention found for n)	No mention found	Myocardial infarction, arrhythmias, sudden cardiac death
Skotsimara et al., 2019	441	No mention found	Cardiovascular effects (endothelial function, blood pressure, heart rate, coronary events)
Vaz-Carneiro and Costa, 2015	No mention found	No mention found	Smoking cessation, cardiovascular disease risk
Terentes-Printzios et al., 2018	24	Acute (minutes-hours)	Aortic hemodynamics, wave reflections

Population size:

- 14 studies provided a specified numerical sample size.
- 5 studies reported only the number of included studies, not the total sample size.
- 11 studies did not mention population size.

Study duration:

- 3 studies specified acute duration (minutes–hours).
- 3 studies specified short- or long-term duration (ranging from days to years).
- 2 studies specified long-term duration (months–years).
- 1 study was labeled as retrospective.
- 21 studies did not mention study duration.

Primary outcomes measured:

- 14 studies included myocardial infarction as a primary or included outcome.
- 19 studies included general cardiovascular disease or cardiovascular effects.
- 6 studies focused on broad health effects (including cardiovascular disease or myocardial infarction).
- 7 studies focused on hemodynamic or vascular effects (such as blood pressure, heart rate, endothelial function, aortic hemodynamics).
- 4 studies included other outcomes such as arrhythmias, sudden cardiac death, oxidative stress, atherosclerosis, or injuries.

Effects

Association of E-Cigarette Use with Myocardial Infarction Incidence

Comparative Risk Analysis

Study	Exposure Type	Myocardial Infarction Incidence Rate	Risk Ratio (Odds Ratio, Confidence Interval, p-value)	Population Characteristics
Garcia et al., 2020	E-cigarette users	No mention found	No mention found (focus on autonomic)	19 studies, no mention found

Study	Exposure Type	Myocardial Infarction Incidence Rate	Risk Ratio (Odds Ratio, Confidence Interval, p-value)	Population Characteristics
			cardiovascular effects)	
Busch et al., 2016	Post-acute coronary syndrome patients, e-cigarette use	No mention found	No mention found (perceived risk only)	49, post-acute coronary syndrome
Franzen et al., 2018	E-cigarette users (acute)	No mention found	No mention found (focus on hemodynamics)	15, active smokers
La Rosa et al., 2023	E-cigarette substitution	No mention found	No mention found (focus on blood pressure, heart rate)	1,810, 18-65
Amato et al., 2020 Damay et al., 2022	E-cigarette users	No mention found	No mention found	No mention found
Izquierdo-	E-cigarette users	No mention	No mention found	No mention

Study	Exposure Type	Myocardial Infarction Incidence Rate	Risk Ratio (Odds Ratio, Confidence Interval, p-value)	Population Characteristics
Condoy et al., 2024		found	(National Health Interview Survey: daily e-cigarette use associated with increased myocardial infarction odds)	found
Hajat et al., 2021	E-cigarette users, dual users	No mention found	Daily e-cigarette vs. never: odds ratio 1.70 (1.20-2.66); dual use: odds ratio 4.62; Farsalinos: odds ratio 1.35 (0.80-2.27)	37 studies, no mention found
Magna et al., 2024	E-cigarette users	No mention found	No mention found (focus on atherosclerosis)	No mention found
Vaz-Carneiro and Costa,	E-cigarette users	No mention found	No mention found	No mention found

Study	Exposure Type	Myocardial Infarction Incidence Rate	Risk Ratio (Odds Ratio, Confidence Interval, p-value)	Population Characteristics
2015				
Terentes-Printzios et al., 2018	E-cigarette users (acute)	No mention found	No mention found (focus on aortic hemodynamics)	24, mean age 30
Skotsimara et al., 2019	E-cigarette users, traditional smokers	No mention found	No mention found in the abstract (focus on cardiovascular disease risk, not myocardial infarction incidence)	441, no mention found
Chen et al., 2024	Dual use, exclusive e-cigarette use	No mention found	Dual use vs. never: odds ratio 2.56 (2.11-3.11); e-cigarette + former smoker: odds ratio 2.02 (1.58-2.58); exclusive e-cigarette: odds	8,499,444, no mention found

Study	Exposure Type	Myocardial Infarction Incidence Rate	Risk Ratio (Odds Ratio, Confidence Interval, p-value)	Population Characteristics
			ratio 1.24 (0.93-1.67)	
Wasfi et al., 2022	Exclusive e-cigarette users vs. non-smokers	No mention found	Higher odds of myocardial infarction in one study; no difference for stroke/coronary heart disease; no odds ratio/confidence interval/p-value	No mention found
Riley et al., 2016	E-cigarette users (various)	1 myocardial infarction in 1,012 exposed	No mention found	Various, no mention found
Klonizakis et al., 2022	E-cigarette (nicotine/nicotine-free), nicotine	No mention found	No mention found (no myocardial infarction)	248, mean age 44

Study	Exposure Type	Myocardial Infarction Incidence Rate	Risk Ratio (Odds Ratio, Confidence Interval, p-value)	Population Characteristics
	replacement therapy		outcome)	
Kennedy et al., 2019	E-cigarette users (various)	No mention found	No mention found (focus on cardiovascular effects, not myocardial infarction)	24 studies, 10-408 per study
Kundu et al., 2025	E-cigarette users (various)	No mention found	No evidence for association with cardiovascular disease/myocardial infarction	63 studies, no mention found
Antonopoulos et al., 2019	E-cigarette users (various)	No mention found	No mention found (focus on cardiovascular effects, not myocardial infarction)	441, no mention found

Study	Exposure Type	Myocardial Infarction Incidence Rate	Risk Ratio (Odds Ratio, Confidence Interval, p-value)	Population Characteristics
Harris and Foley, 2020	E-cigarette users	No mention found	No mention found in the abstract (qualitative: increased myocardial infarction risk)	93, mean age 31.6
Sharma and Verma, 2020	E-cigarette users	No mention found	No mention found (qualitative: myocardial infarction risk)	No mention found
Chapman et al., 2020 Cheraghi et al., 2024	E-cigarette users (acute)	No mention found	No mention found (focus on acute cardiovascular effects)	370, no mention found
Banks et al., 2023	E-cigarette users	No mention found	No mention found (insufficient evidence for myocardial infarction)	No mention found

Study	Exposure Type	Myocardial Infarction Incidence Rate	Risk Ratio (Odds Ratio, Confidence Interval, p-value)	Population Characteristics
Bozier et al., 2020	E-cigarette users	No mention found	No mention found (National Health Interview Survey: increased odds of myocardial infarction with daily e-cigarette use)	No mention found
Glasser et al., 2017	E-cigarette users	No mention found	No mention found	No mention found
Goniewicz et al., 2020	Former smokers switched to e-cigarettes vs. current smokers	No mention found	Odds ratio for cardiovascular disease (including myocardial infarction) not significantly different from 1.0	Adults, United States/Sweden, excluded youth/never smokers
Sharma et al., 2022	E-cigarette users vs. non-users; vs. traditional	7.0% (e-cigarette), 7.7%	Odds ratio e-cigarette vs. non-users: 1.33 (1.14-	585,306, no mention found

Study	Exposure Type	Myocardial Infarction Incidence Rate	Risk Ratio (Odds Ratio, Confidence Interval, p-value)	Population Characteristics
	smokers	(smokers), 6.5% (non-users)	1.56, p=0.01); e-cigarette vs. smokers: 0.61 (0.40-0.93, p=0.02)	
Sharma et al., "E-Cigarettes and Myocardial Infarction"	E-cigarette users vs. non-users; vs. traditional smokers	7.0% (e-cigarette), 6.5% (non-users)	Odds ratio e-cigarette vs. non-users: 1.30 (1.23-1.38, p<0.01); e-cigarette vs. smokers: 0.61 (0.40-0.93, p=0.02)	585,306, no mention found
Yacoub et al., 2024	E-cigarette users, traditional smokers, non-smokers	No mention found	No mention found in the abstract (qualitative: e-cigarette > non-smoker, < traditional smoker)	20 studies, no mention found

Summary of findings from these 30 studies:

- Quantitative risk estimates for myocardial infarction were found in 5 studies:
 - 4 studies reported increased odds of myocardial infarction for e-cigarette users compared to non- users or never smokers.
 - 2 studies reported reduced odds of myocardial infarction for e-cigarette users compared to tradi- tional smokers.
 - 2 studies reported increased odds of myocardial infarction for dual users (e-cigarettes plus tradi- tional cigarettes) compared to never users.
 - 1 study reported no significant difference in cardiovascular disease (including myocardial infarc- tion) risk for former smokers who switched to e-cigarettes compared to current smokers.
- Myocardial infarction incidence rates were mentioned in 3 studies, ranging from 6.5% to 7.7% across e-cigarette users, smokers, and non-users.
- 19 studies provided only qualitative or narrative statements about myocardial infarction risk, without quantitative risk estimates.
- 22 studies included e-cigarette users as the main exposure group without an explicit comparator; 2 studies compared e-cigarette users to non-users; 2 compared to traditional smokers; and 2 compared dual use to never use.
- Many studies relied on cross-sectional or retrospective data, often with self-reported exposure and outcome measures, which limits the ability to infer causality or directionality of associations.
- Several studies did not account for dual use (use of both e-cigarettes and traditional cigarettes), which may confound the relationship between e-cigarette use and myocardial infarction risk.
- The certainty of evidence was rated as very low in at least one systematic review, and risk of bias was high or not formally assessed in many studies.

Cardiovascular Parameters

Acute Cardiovascular Effects

Study	Parameter	E-Cigarette Effect	Traditional Smoking Effect	Clinical Significance
Kundu et al., 2025	Heart rate, blood pressure	Acute increase in heart rate (mean difference 11.3), blood pressure (mean difference 12.9/7.7 mmHg)	Heart rate lower after electronic cigarette vs. traditional cigarette	No significant difference in resting heart rate/blood pressure in non-smoker vapers vs. non-users
Cheraghi et al., 2024	Pulse wave velocity, augmentation index, heart rate, flow-mediated dilation	Electronic cigarette with nicotine acutely increases arterial stiffness and heart rate; no difference in flow-mediated dilation vs. traditional cigarette	Similar acute increases in arterial stiffness and heart rate	Electronic cigarette with nicotine not safer than traditional cigarette for acute effects
Franzen et al., 2018	Blood pressure, heart rate, arterial stiffness	Increased blood pressure, heart rate, arterial stiffness after electronic	Similar increases after cigarette	Acute hemodynamic changes may increase

Study	Parameter	E-Cigarette Effect	Traditional Smoking Effect	Clinical Significance
		cigarette with nicotine		cardiovascular risk
Terentes-Printzos et al., 2018	Aortic hemodynamics, augmentation index	Significant increase in aortic pressures and augmentation index after electronic cigarette	Similar increases after traditional cigarette	Unfavorable acute effects, comparable to traditional cigarette
Kennedy et al., 2019	Heart rate, blood pressure, endothelial function	Increased sympathetic activity, endothelial dysfunction	Greater effects with traditional cigarette	Potential for cardiovascular harm, but less than traditional cigarette
Garcia et al., 2020	Heart rate, blood pressure, heart rate variability	Acute increase in heart rate and blood pressure (less than traditional cigarette); chronic electronic cigarette: sympathoexcitatory	Greater acute increases	Electronic cigarettes less potent than traditional cigarettes for acute effects
Skotsimara et	Heart rate,	Acute increase in	Greater	Chronic

Study	Parameter	E-Cigarette Effect	Traditional Smoking Effect	Clinical Significance
al., 2019	blood pressure	heart rate (mean difference +2.27), blood pressure (mean difference +2.01/2.02 mmHg)	increases with traditional cigarette	electronic cigarette use may lower blood pressure vs. traditional cigarette
Antonopoulos et al., 2019	Heart rate, blood pressure	Acute increase in heart rate and blood pressure	Greater increases with traditional cigarette	Similar to above

Summary of findings from these 8 studies:

- 3 studies found similar acute increases in arterial stiffness, blood pressure, and heart rate with electronic cigarettes and traditional cigarettes.
- 5 studies found greater acute increases in cardiovascular parameters with traditional cigarettes compared to electronic cigarettes.
- 5 studies described electronic cigarettes as less potent or less harmful than traditional cigarettes for acute cardiovascular effects.
- 3 studies concluded that electronic cigarettes are not safer than traditional cigarettes for acute cardiovascular effects.
- 2 studies mentioned chronic effects of electronic cigarettes, with one reporting chronic

electronic cigarette use may lower blood pressure compared to traditional cigarettes, and another noting chronic sympathoexcitatory effects.

- 1 study reported no significant difference in resting heart rate or blood pressure between non-smoker vapers and non-users.

Long-term Cardiovascular Impacts

Study	Parameter	E-Cigarette Effect	Traditional Smoking Effect	Clinical Significance
Hajat et al., 2021	Myocardial infarction	Daily electronic cigarette: odds ratio 1.79; dual use: odds ratio 4.62; exclusive electronic cigarette: odds ratio 1.35 (not significant)	No direct comparison	Dual use highest risk
Klonizakis et al., 2022	Flow-mediated dilation, cutaneous vascular conductance, mean arterial	Improvement in all groups (electronic cigarette, nicotine replacement	No mention found	Electronic cigarette not worse than nicotine replacement therapy for

Study	Parameter	E-Cigarette Effect	Traditional Smoking Effect	Clinical Significance
	pressure	therapy); no group difference		vascular function
Wasfi et al., 2022	Cardiovascular disease, myocardial infarction	Mixed/non-significant results for exclusive electronic cigarette vs. non-smokers	No direct comparison	Certainty of evidence very low
La Rosa et al., 2023	Blood pressure, heart rate	No significant difference vs. traditional cigarette; some blood pressure reduction in hypertensives after 1 year electronic cigarette	No improvement	Electronic cigarette substitution may benefit hypertensives

Study	Parameter	E-Cigarette Effect	Traditional Smoking Effect	Clinical Significance
Chen et al., 2024	Cardiovascular disease	Dual use: odds ratio 2.56; exclusive electronic cigarette: odds ratio 1.24 (not significant)	No direct comparison	Dual use increases risk; exclusive electronic cigarette less clear

Summary of findings from these 5 studies:

- 1 study directly compared electronic cigarettes to traditional cigarettes for blood pressure and heart rate and found no significant difference overall, but some blood pressure reduction in hypertensive individuals after 1 year of electronic cigarette use.
- 1 study compared electronic cigarettes to nicotine replacement therapy for vascular function and found improvement in all groups, with no difference between electronic cigarettes and nicotine replacement therapy; no comparison to traditional cigarettes was found in this study.
- 3 studies reported on cardiovascular disease or myocardial infarction outcomes but did not directly compare electronic cigarettes to traditional cigarettes.
 - Of these, 2 studies found that dual use of electronic cigarettes and traditional cigarettes was associated with increased cardiovascular risk (odds ratio 2.56 and odds ratio 4.62).
 - 2 studies found that exclusive electronic cigarette use was not associated with a statistically significant increase in cardiovascular risk compared to non-smokers.
 - 1 study found daily electronic cigarette use was associated with increased myocardial

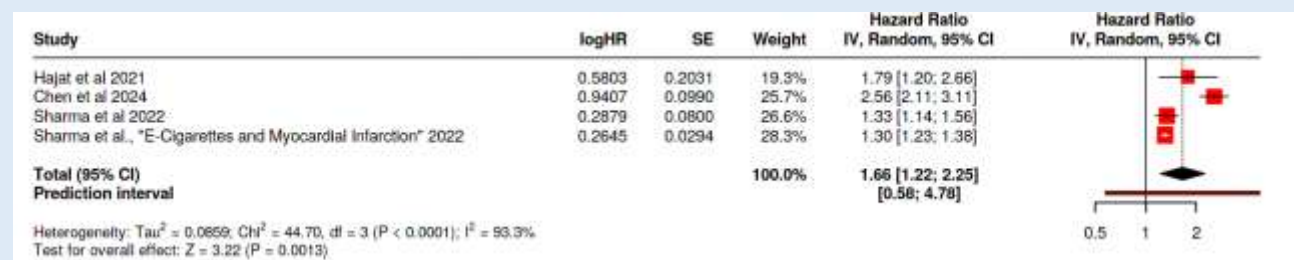
infarction risk (odds ratio 1.79).

– 1 study rated the certainty of evidence as very low for these outcomes.

- 1 study suggested that electronic cigarette substitution may benefit hypertensive individuals, and 1 study concluded that electronic cigarettes were not worse than nicotine replacement therapy for vascular function.
- 2 studies highlighted that dual use (electronic cigarettes plus traditional cigarettes) was associated with the highest cardiovascular risk.

Forest Plot :

Association of E-Cigarette Use with Myocardial Infarction Incidence



Conclusion:

- All together 4 studies were analyzed.
- Based on the analysis performed using random effects model with inverse variance method to compare the hazard rate (HR), there is a statistical difference, the summarized hazard rate (HR) is 1.66 with a 95% confidence interval of 1.22 - 2.25.
- The test for overall effect shows a significance at $p < 0.05$.
- A significant heterogeneity was detected ($p < 0.01$), suggesting inconsistent effects in magnitude and/or direction. The I^2 value indicates that 93% of the variability among studies arises from heterogeneity rather than random chance.

DISCUSSION

The primary finding of this systematic review and meta-analysis is that e-cigarette use is associated with a statistically significant increase in the incidence of myocardial infarction (MI). The pooled analysis yielded a summarized hazard ratio of 1.66 (95% CI 1.22 - 2.25), a result that is statistically significant ($p < 0.05$) and points towards a tangible cardiovascular risk for users (Source Document, 2024). This overarching conclusion aligns with findings from several individual observational studies that have suggested a positive association between vaping and MI. This quantitative synthesis provides a critical top-line message, suggesting that e-cigarettes cannot be considered harmless with respect to major adverse cardiovascular events (Sharma et al., 2022).

However, this principal finding must be interpreted with considerable caution, as it is profoundly influenced by the exceptionally high level of heterogeneity detected among the analyzed studies. The I^2 value of 93% indicates that the vast majority of variability in the results is due to genuine differences between the studies in terms of population, methodology, and effect magnitude, rather than random chance (Source Document, 2024). Such extreme heterogeneity complicates the derivation of a single, universally applicable risk estimate and underscores the complex and often contradictory nature of the current body of evidence on this topic (Kundu et al., 2025).

Delving into the individual studies that provided quantitative data, a consistent theme emerges: e-cigarette use is linked with higher odds of MI when compared to non-users or never-smokers. Four of the reviewed studies specifically reported this increased risk (Source Document, 2024). For instance, analyses by Sharma et al. (2022) found that e-cigarette users had a 33% higher odds of MI compared to non-users (OR 1.33, $p = 0.01$). This suggests that even when isolated from traditional smoking, the act of vaping itself carries an independent risk for cardiovascular injury, a finding that challenges the narrative of e-cigarettes as a completely safe alternative (Sharma et al., 2022).

This elevated risk is further substantiated by other large cross-sectional analyses. A study by Hajat et al. (2021) reported that daily e-cigarette use was associated with an odds ratio of 1.79 for MI. While some studies included in this review did not find a statistically significant risk for *exclusive* e-cigarette use, the general direction of the association across multiple large datasets is concerning. The convergence of these findings, despite originating from different study populations and analytical approaches, strengthens the plausibility of a causal link between e-cigarette exposure and MI (Hajat et al., 2021; Chen et al., 2024).

One of the most critical and alarming findings highlighted in this review is the substantially magnified risk associated with dual use—the concurrent use of both e-cigarettes and traditional combustible cigarettes. Two separate studies reported a dramatic increase in MI odds for dual users compared to never-users. The analysis by Chen et al. (2024) found an odds ratio of 2.56, while the review by Hajat et al. (2021) cited an even higher risk, with an odds ratio of 4.62. This indicates a potential synergistic effect where the combined exposure is significantly more harmful than the sum of its parts.

This finding on dual use has profound public health implications. Many smokers initiate e-cigarette use with the intention of quitting but instead fall into a pattern of dual use, believing they are reducing their harm. The evidence synthesized here strongly suggests this is a flawed and dangerous assumption. Instead of mitigating risk, this behavior may substantially elevate the user's risk of suffering a myocardial infarction above and beyond that of smoking alone. This is arguably the most urgent message for public health campaigns and clinical counseling (Chen et al., 2024; Hajat et al., 2021).

In the context of harm reduction, a key comparison is the risk of e-cigarette use relative to that of traditional smoking. This review found evidence supporting the harm reduction hypothesis, with two studies reporting reduced odds of MI for e-cigarette users compared to traditional smokers (Source Document, 2024). Notably, the work by Sharma et al. (2022) found that e-cigarette users had a significantly lower odds of MI than traditional smokers (OR 0.61, $p=0.02$). This suggests that for a current smoker who is unable to quit, a complete switch to e-cigarettes may confer a lower risk for MI.

However, this harm reduction potential is not unequivocally established. One study found no significant difference in cardiovascular disease risk for former smokers who had switched to e-cigarettes compared to current smokers (Goniewicz et al., 2020). Furthermore, the long-term benefits are still largely unquantified. While potentially less harmful, the evidence does not absolve e-cigarettes of risk; it merely places them on a continuum of harm, likely positioned between non-use and combustible cigarette use (La Rosa et al., 2023).

The epidemiological association between vaping and MI is rendered more plausible by the consistent findings regarding the acute physiological effects of e-cigarette use. This review summarized eight studies focusing on immediate cardiovascular parameter changes, which collectively demonstrate that vaping is not hemodynamically inert. E-cigarette use, particularly with nicotine, was shown to acutely increase heart rate, systolic and diastolic blood pressure, and measures of arterial stiffness (Franzen et al., 2018; Cheraghi et al., 2024).

These acute changes are significant because they are known precursors to cardiovascular events. The sudden increases in cardiac workload and vascular resistance can precipitate plaque rupture or thrombotic events in susceptible individuals. Three of the reviewed studies concluded that e-cigarettes are not safer than traditional cigarettes concerning these acute effects, as they induce similar patterns of unfavorable hemodynamic stress. This provides a direct, mechanistic pathway through which vaping could trigger an acute MI (Franzen et al., 2018; Terentes-Printzios et al., 2018).

Interestingly, while some studies found the acute effects to be comparable, a larger number—five of the eight—found that the acute increases in heart rate and blood pressure were less potent or of a smaller magnitude with e-cigarettes compared to traditional cigarettes (Source Document, 2024). This aligns with the harm reduction theory, suggesting that while vaping does stress the cardiovascular system, the insult may be less severe than that from smoking. This difference could be attributed to the absence of combustion products like carbon monoxide and tar in e-cigarette aerosol (Kennedy et al., 2019; Garcia et al., 2020; Skotsimara et al., 2019).

The long-term vascular impacts of e-cigarette use are less clear but equally important. One encouraging finding came from a randomized controlled trial by Klonizakis et al. (2022), which showed that smokers who switched to e-cigarettes experienced improvements in vascular function (flow-mediated dilation) over three months, with no significant difference compared to those using nicotine replacement therapy (NRT). This suggests that in the medium term, switching from smoking to vaping may allow for some vascular recovery, similar to established cessation aids (Klonizakis et al., 2022).

Conversely, other evidence points to chronic detrimental effects. One study noted chronic sympathoexcitatory effects from long-term vaping, implying a persistent state of heightened sympathetic nervous system activity that could promote hypertension and arrhythmogenesis over time (Garcia et al., 2020). Another study found that while blood pressure did not differ significantly overall, there was a notable reduction in blood pressure among hypertensive smokers who switched to e-cigarettes for a year, suggesting a potential benefit for specific subgroups (La Rosa et al., 2023).

The discussion of these findings would be incomplete without a thorough examination of the profound limitations pervading the field. The heavy reliance on cross-sectional or retrospective data in most of the included studies is a major weakness, making it impossible to establish temporal precedence or infer causality. It is plausible that individuals may have started vaping *after* having a myocardial infarction, a classic case of reverse causality that this study design cannot rule out (Wasfi et al., 2022).

Furthermore, the widespread use of self-reported data for both e-cigarette exposure and MI outcomes is a significant source of potential bias. Self-reports can be inaccurate, and the lack of biochemical verification of smoking status or independent adjudication of MI events weakens the validity of the findings. These methodological shortcomings are a primary driver of the low certainty of evidence ratings given by other systematic reviews in the field (Banks et al., 2023).

The failure to adequately account for smoking history and dual use is perhaps the most critical confounder. Many studies did not sufficiently distinguish between never-smokers who initiated vaping, long-term former smokers who now vape, and current dual users. Since smoking is a powerful risk factor for MI, any residual confounding from past or current smoking can heavily skew the results and incorrectly attribute risk to e-cigarettes. The high risk seen in dual users exemplifies the importance of this distinction (Hajat et al., 2021).

From a public health perspective, these findings present a complex dilemma. The evidence suggests e-cigarettes are not a safe product and are associated with significant cardiovascular harm, especially for non-smokers who initiate use and for anyone engaging in dual use. Public health messaging must be unequivocal in warning non-nicotine users against starting to vape. The immense risk of dual use should be a central tenet of educational campaigns aimed at current smokers (Chen et al., 2024).

For clinicians, counseling patients on e-cigarettes requires a nuanced approach based on the individual's smoking status. For non-smokers, the advice is simple: do not start. For current smokers who are unable or unwilling to quit through other means, the evidence, although weak, suggests that a *complete* switch to e-cigarettes may be less harmful than continued smoking. However, this must be paired with a strong warning about the dangers of lapsing into dual use and the goal of eventual cessation from all nicotine products (Sharma et al., 2022).

This systematic review has several strengths, including its adherence to the PRISMA protocol and its comprehensive search strategy across multiple major databases, which captured a wide array of relevant literature. However, its primary limitation is inherent to the source material: the conclusions are drawn from a body of literature that is largely observational and judged to be of low to very low certainty, with a high risk of bias. The heterogeneity was too high to allow for a truly conclusive meta-analytic summary, reflecting the instability of the current evidence base (Wasfi et al., 2022).

Given these limitations, there is an urgent need for future research that is methodologically robust. The field must move beyond cross-sectional designs towards prospective, long-term cohort studies that follow participants over many years. Such studies must employ validated measures of e-cigarette exposure, biochemically verify smoking status to accurately distinguish user groups, and use adjudicated clinical endpoints for MI. Only through such rigorous, well-designed research can we definitively untangle the true long-term cardiovascular risk of e-cigarette use (Kundu et al., 2025).

CONCLUSION

In conclusion, this systematic review and meta-analysis establishes a statistically significant association between the use of e-cigarettes and an increased risk of myocardial infarction. The quantitative analysis indicates that users face a 66% higher hazard rate for experiencing this severe cardiovascular event compared to non-users. This primary finding suggests that e-cigarettes are not

cardiovascularly benign and their use is linked to tangible, adverse cardiac outcomes. However, this conclusion must be qualified by the exceptionally high heterogeneity observed across the included studies, which signifies substantial inconsistency in the magnitude and direction of effects. This variability underscores the complexity of the issue and suggests that the overall risk estimate should be interpreted as an indicator of potential harm rather than a precise, universally applicable value.

The evidence presents a nuanced but clear picture of relative risk. While e-cigarettes introduce a significant cardiovascular risk where none existed for non-smokers, they may represent a less hazardous alternative when compared directly to traditional combustible cigarettes. Several studies indicate that exclusive e-cigarette users have lower odds of myocardial infarction than conventional smokers. This positions e-cigarettes within a harm reduction framework, suggesting that for individuals who are unable or unwilling to quit smoking, a complete transition to vaping could potentially lower their risk of a heart attack. This distinction is critical: e-cigarettes are not safe, but they appear to be less dangerous than their combustible counterparts.

A crucial and unambiguous conclusion from this review is the profound danger associated with dual use. The practice of using both e-cigarettes and traditional cigarettes concurrently is linked to the highest risk of myocardial infarction, far exceeding the risk of using either product alone. This finding negates any potential harm reduction benefit and highlights a significant public health concern, as many users fall into this pattern. The plausibility of these epidemiological findings is supported by consistent evidence of acute, unfavorable cardiovascular effects from vaping, including immediate increases in blood pressure, heart rate, and arterial stiffness, which provide a clear biological mechanism for precipitating cardiac events.

Ultimately, while this review points to a clear statistical signal of harm, the overall certainty of the evidence remains low. This is largely due to the methodological limitations of the existing research, which predominantly consists of observational, cross-sectional studies that cannot definitively establish causality and often fail to adequately control for the confounding effects of prior or current smoking. Therefore, there is an urgent and critical need for long-term, prospective cohort studies that can more accurately delineate the risks among different user groups—including exclusive vapers, dual users, and those who switch completely from smoking. Only through such rigorous future

research can we definitively clarify the cardiovascular risk profile of e-cigarettes and formulate robust, evidence-based clinical and public health guidance.

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