RESEARCH

The prognostic value of Tei index in acute myocardial infarction: a systematic review

Sadie Bennett[1], **Chun Wai Wong**[1,2], **Timothy Griffiths**[1], **Martin Stout**[3], **Jamal Nasir Khan**[4], **Simon Duckett**[1], **Grant Heatlie**[1] and **Chun Shing Kwok**[1,2]

[1]Royal Stoke University Hospital, Stoke-on-Trent, UK
[2]Primary Care & Health Sciences, Keele University, Stoke-on-Trent, UK
[3]Manchester University NHS Foundation Trust, Manchester, UK
[4]University Hospitals of Coventry & Warwickshire, Coventry, UK

Correspondence should be addressed to S Bennett: sadie.bennett@uhnm.nhs.uk

Abstract

Background: Echocardiographic evaluation of left ventricular ejection fraction (LVEF) is used in the risk stratification of patients with an acute myocardial infarction (AMI). However, the prognostic value of the Tei index, an alternative measure of global cardiac function, in AMI patients is not well established.
Methods: We conducted a systematic review, using MEDLINE and EMBASE, to evaluate the prognostic value of the Tei index in predicting adverse outcomes in patients presenting with AMI. The data was collected and narratively synthesised.
Results: A total of 16 studies were including in this review with 2886 participants (mean age was 60 years from 14 studies, the proportion of male patients 69.8% from 14 studies). Patient follow-up duration ranged from during the AMI hospitalisation stay to 57.8 months. Tei index showed a significant association with heart failure episodes, reinfarction, death and left ventricular thrombus formation in 14 out of the 16 studies. However, in one of these studies, Tei index was only significantly predictive of cardiac events in patients where LVEF was <40%. In two further studies, Tei index was not associated with predicting adverse outcomes once LVEF, left ventricular end-systolic volume index and left ventricular early filling time was taken into consideration. In the two remaining studies, there was no prognostic value of Tei index in relation to patient outcomes.
Conclusions: Tei index may be an important prognostic marker in AMI patients, however, more studies are needed to better understand when it should be used routinely within clinical practice.

Key Words

- echocardiography
- Tei index
- myocardial performance index
- myocardial infarction
- prognosis

Introduction

First described in 1995 (1), the Tei index, also known as a myocardial performance index, is a ratio of systolic and diastolic time intervals which can be easily obtained from Doppler echocardiography. This timing ratio, characterised by the sum of the isovolumetric contraction time and isovolumetric relaxation time divided by the overall ejection time, has been well validated in the assessment of overall global myocardial performance in both adult and paediatric populations (1, 2). Although Tei index is not a frequently used measurement in assessing cardiac function in current clinical practice, there is evidence to suggest that the Tei index is a simple,

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reliable and reproducible measurement in patients with congestive heart failure, congenital heart disease and cardiac rejection post-transplantation (3). Tei index has also been shown to have prognostic value in patients with cardiac amyloidosis and dilated cardiomyopathy (4, 5).

An acute myocardial infarction (AMI) is a leading cause of morbidity and mortality worldwide (6) with known complications including congestive heart failure, functional and structural myocardial abnormalities, reinfarction and death. In the setting of an AMI, echocardiography is a well-established risk stratification tool (7, 8). Consequently, echocardiographic assessment in the early post-AMI stage forms part of national and international guidelines (9, 10). An important echocardiographic measurement for post-AMI patients is the assessment of left ventricular systolic function via left ventricular ejection fraction (LVEF) which is well associated with short-term and long-term outcomes (11, 12, 13). However, it is well recognised that systolic and diastolic function are tightly connected at a cellular, myocardial and hemodynamic level (14). As such, Tei index, which considers both contraction and relaxation timing intervals, may provide important prognostic information in patients presenting with AMI which may go unmissed with the isolated evaluation of LVEF. Furthermore, the Tei index is less affected by image quality compared to LVEF and GLS which makes the index an attractive parameter for the assessment of global left ventricular function.

Studies in the literature evaluating the prognostic value Tei index after AMI are inconsistent with studies reporting an association between a greater Tei index and adverse events (15, 16, 17, 18). Whilst other studies either conclude there to be no association (19) or, that Tei index offer no additional benefit over the more routinely used LVEF measurement (20). In view of the importance of understanding the prognostic value of the Tei index in AMI patients and the inconsistencies reported, we conducted a systematic review of the literature to evaluate what is currently known.

Methods

We conducted a systematic review to evaluate the current literature on the prognostic value of Tei index in patients presenting with an AMI. Tei index was defined as per Fig. 1. Study inclusion criteria included: retrospective cohort studies, prospective cohort studies and matched control studies. Excluded criteria consisted of conference abstracts, animal studies, case studies, case series,

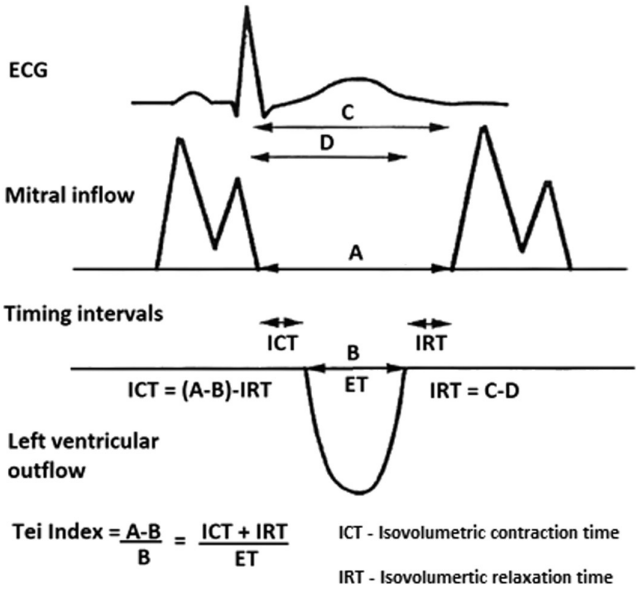

Figure 1
Schematic representation of Tei index.

studies using bare-metal stents used as part of the AMI treatment plan. Studies that analysed the same cohort were also excluded to avoid duplication of results.

A search of MEDLINE and EMBASE was performed on OVID using the search terms 'Tei index', 'myocardial performance index', 'acute coronary syndrome', 'acute myocardial infarction', 'STEMI' in April 2020. The search results were independently reviewed for inclusion by two reviewers (SB and CSK). Full text of potentially relevant studies was downloaded and reviewed for final inclusion. Data extractions were performed by two independent reviewers (SB and CSK). Extracted information included study design, year, country the study was conducted in, number of participants, mean age of participants, percentage of male participants, participant inclusion criteria, echocardiographic findings, prognostic outcomes/clinical outcomes of Tei index. The Newcastle–Ottawa quality assessment scale was used to assess the quality of each included study (21). The Newcastle-Ottawa scale was incorporated into this review as it enables a standardised and comprehensive assessment of nonrandomised studies to be quality assessed against (21). Results from the extractions are presented in tables. The results were narratively synthesised.

Results

Our search results yielded 144 potential inclusions and after detailed screening and review, a total of 16 studies

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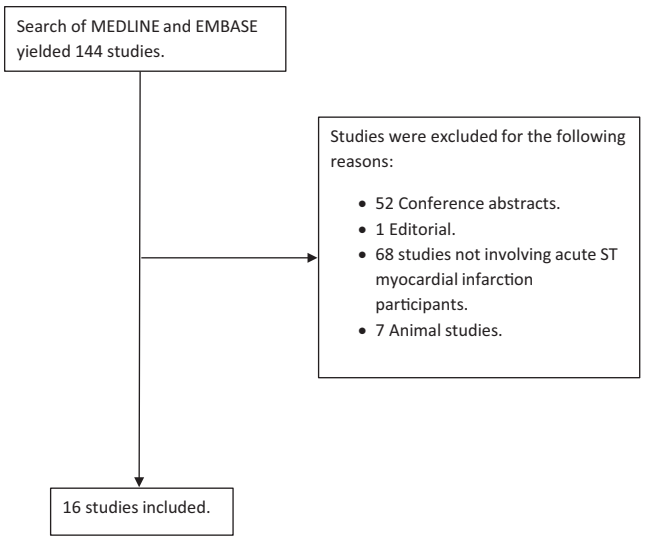

Figure 2
Flow diagram of studies inclusion.

were included in the review (Fig. 2) (6, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29). These studies included 14 cohort studies and 2 matched control studies (Table 1). In total, 15 out of the 16 studies that reported when the studies had been conducted showed that the studies were performed between 1995 and 2015. The studies took place around the world including Denmark, Norway, Egypt, Japan, Israel, Brazil, Poland, Turkey, Sweden and Romania. Overall, there were a total of 2886 participants with individual study participant numbers ranging from 44 to 417. From 14 studies that reported mean age of participants, the average overall age was 60 years. From 14 studies which reported participant sex, the overall mean percentage of male participants was 69.8%. Only 7 of the 16 included studies, included patients with first AMI. Detailed echocardiographic parameters that were reported in each of the included studies are shown in Supplementary Table 1 (see section on supplementary materials given at the end of this article).

All studies used transthoracic echocardiography to assess Tei index, 3 of which used tissue Doppler image with the remaining studies using trans-mitral and left ventricular outflow time intervals obtained from either continuous or pulsed wave Doppler studies. Of the 16 studies, 10 included all coronary territory AMI patients, two studies included only anterior AMI patients, one included only anteroseptal AMI patients, the three studies did not comment on the coronary territory. Twelve studies indicated that the Tei index measurements were undertaken during the same hospitalisation of the AMI. However, the timing of the Tei index measurement

Table 1 Description of studies.

Study ID	Study design; Country; Year	No. of patients	Mean age	Male %	Inclusion criteria	Exclusion criteria
Abuomara 2018	Prospective cohort study; Egypt; 2014–2015	60	54	70	Patients with first acute anterior STEMI treated with primary PCI.	Known dilated cardiomyopathy, previous PCI or CABG, non-sinus rhythm.
Biering-Sørensen 2013	Prospective cohort study; Denmark; 2006–2008	386	62	75	Patients with STEMI treated with primary PCI.	Poor quality echocardiography images.
Hole 2003	Prospective cohort study; Norway; 1995–1997	71	65	73	Patients in sinus rhythm with AMI without heart failure.	Unstable angina requiring PCI, CABG, heart failure, AF, comorbid non-cardiac disease reducing life expectancy <2 years.
Karvounis 2004	Matched control study; Greece; unclear	68	53	78	Patients who survived AMI who received thrombolysis.	Previous Q wave myocardial infarction, AF, moderate to severe mitral regurgitation, severe aortic stenosis.
Møller 2001	Prospective cohort study; Denmark; unclear	125	68	Unclear	Patients with first AMI.	Aortic stenosis, implanted pacemaker and dementia.
Møller 2003	Prospective cohort study; Denmark; 1998–1999	799	Median 69	68	Patients with definite AMI.	Incomplete Doppler echocardiography.
Rahman 2009	Prospective cohort study; Pakistan; 2006–2007	202	Unclear	78	Patients with AMI.	Significant mitral regurgitation or aortic stenosis, inadequate echo images, congenital heart disease.

(*Continued*)

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Table 1 Continued.

Study ID	Study design; Country; Year	No. of patients	Mean age	Male %	Inclusion criteria	Exclusion criteria
Sasao 2004	Matched control study; Japan; 2000–2001	53	63	72	Patients with first AMI treated with primary PCI.	Slow flow after post-PCI, presence of mechanical complications, previous myocardial infarction, AF, CABG, recent PCI, inadequate recording of echocardiography.
Schwammenthal 2003	Cohort study; Israel; unclear	417	62	78	Patients with AMI.	Patients who did not have echo evaluation.
Souza 2011	Prospective cohort study; Brazil; unclear	95	58	67	Patients with first STEMI.	Previous AMI, early reinfarction, early reinfarction, in-hospital death, previous CABG or PCI, left bundle branch block, non-sinus rhythm, valvular heart disease, dilated cardiomyopathy, poor echocardiography images.
Szymanski 2002	Prospective cohort study; Poland; unclear	90	58	71	Patients who were hospital survivors of AMI.	AF, sinus tachycardia, significant mitral/aortic stenosis/ regurgitation, inadequate echocardiography studies.
Uzunhasan 2006	Prospective cohort study; Turkey; 2001–2002	77	53	75	Patients with transmural first myocardial infarction.	AF, permanent pacemaker, dementia, aortic stenosis, inappropriate Doppler recordings, chronic obstructive pulmonary disease.
Westholm 2013	Prospective cohort study; Sweden; 2006–2008	227	67	76	Patients admitted with an AMI.	None.
Yilman 2004	Prospective cohort study; Turkey; unclear	92	58	88	Patients with first anterior AMI.	Rhythm and conduction abnormalities, prior AMI, cardiomyopathy, valvular heart disease, lung disease, pulmonary hypertension, patients who underwent PCI, poor echocardiography images
Yuasa 2005	Cohort study; Japan; unclear	80	64	78	Patients with first anteroseptal AMI.	Multiple infarctions, congenital, pericardial and organic valvular heart disease.
Zamfir 2016	Prospective cohort study; Romania; 2015–2016	44	63	70	Patients with acute STEMI treated with primary PCI.	Previous history of cardiac or pulmonary disease.

AF, atrial fibrillation; AMI, acute myocardial infarction; CABG, coronary artery bypass graft; PCI, percutaneous coronary intervention; STEMI, ST elevation myocardial infarction.

in relation to the AMI event varied within 1 h of the angioplasty procedure to within 7 days of AMI. Table 2 shows the quality assessment which was undertaken on all of the included studies in this review. The Newcastle-Ottawa Quality assessment tool indicated that 3 out of 16 studies were of fair quality while the remaining studies were of good quality. Of the 16 included studies, 14 studies indicated that a high Tei index value showed a significant association with heart failure episodes, reinfarction, death and left ventricular thrombus (Table 3). These are discussed separately below.

Tei index and mortality studies

In the study by Karvounis *et al.*, Tei index was greater among patients with Killip class II and III compared to Killip class I at both 1 day follow-up and 1 month follow-up. The mortality rate at 1 year was higher with Killip class II and III compared to class I (24). For survival, Møller *et al.* found that survival at 1 year was 89% among patients with a Tei index <0.63 compared to 37% with a Tei index ≥0.63. Here, Tei index was associated with an increased risk of cardiac death (RR 5.6 95% CI 2.4–13.0) (15).

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Table 2 Study quality assessment using Newcastle Ottawa Scale.

Study ID	Timing of Tei index measurements	Newcastle-Ottawa Quality assessment			
		Selection domain[a]	Comparability domain[b]	Outcome domain[c]	Overall
Abuomara 2018	Within 24 h of presentation	****	*	**	Good quality
Biering-Sørensen 2013	Within 5 days of admission	***	**	***	Good quality
Hole 2003	Between 2 and 7 days after AMI	***	–	**	Fair quality
Karvounis 2004	Within 24 h of admission and repeated 1 month after AMI	***	*	**	Good quality
Møller 2001	Within 24 h of admission, then on day 5, 1 and 3 months post-AMI	***	–	*	Fair quality
Møller 2003	Within 6 days of AMI	****	*	***	Good quality
Rahman 2009	Unclear	***	–	**	Good quality
Sasao 2004	Within 1 h of angioplasty	***	*	***	Good quality
Schwammenthal 2003	Within 24 h of hospital admission	****	*	***	Good quality
Souza 2011	Within 24 h of arrival at coronary care unit, within 48 h of chest pain	***	*	**	Good quality
Szymanski 2002	14 ± 2 days post-AMI	***	**	**	Good quality
Uzunhasan 2006	Within 24 h of admission	***	–	**	Good quality
Westholm 2013	Median time 3(2–4) days from admission	***	–	***	Good quality
Yilman 2004	Within 24 h of admission	***	*	***	Good quality
Yuasa 2005	At time of admission	***	*	***	Fair quality
Zamfir 2016	Within hospitalisation stay of AMI	***	*	**	Good quality

[a]Selection domain based on: (1) Representativeness of exposed cohort, (2) Selection of the non-exposed cohort, (3) Ascertainment of exposure, 4) Demonstration that outcome of interest was not present at the start of the study; a star (*) is awarded for each of the criteria meet, a maximum of 4 stars can be awarded for this domain; [b]Comparability domain based on: comparability of cohorts on the basis of the design of analysis – *Control for age, **Control for other factors; [c]Outcome domain based on: (1) Assessment of outcome, (2) Was follow-up long enough for outcomes to occur, (3) Adequacy of follow-up of cohorts.
AMI, acute myocardial infarction; LV, left ventricle.

Møller *et al*. also showed that at a median follow-up duration of 34 months, relative to a Tei index of <0.46, there was a two-fold increase in the risk of death with a Tei index value of between 0.46 and 0.68 and a four-fold increase in the risk of death with a Tei index value >0.68 (15). Szymanski *et al*. found that a Tei index >0.55 was associated with a four-fold increase in the risk of cardiac death and nonfatal recurrent myocardial infarction (14). Uzunhasan *et al*. found that Tei index was greater among patients with death and heart failure (26).

Tei index and heart failure studies

Abuomara *et al*. evaluated the value of a Tei index >0.73 compared to a LVEF ≤33% and found that the Tei index was more sensitive (78.3% vs 56.5%) with similar specificity (94.6% vs 94.6%) for in-hospital heart failure after AMI (6). Sasao *et al*. concluded that a greater Tei index (reported as >0.70) was correlated with the development of heart failure episodes (OR 14.139 95% CI 1.269–157.553) (18). Schwammenthal *et al*. found that Tei index ≥0.52 was not predictive of adverse outcomes whilst an LVEF <40% was associated with adverse outcomes (19). Souza *et al*. found that an LVEF ≤45% was associated with increased odds of in-hospital heart failure but only amongst patients ≥60 years of age with a Tei index ≥0.57 (25).

Tei index and composite adverse outcomes

Biering Sørensen *et al*. reported that a greater Tei index value (0.59 ± 0.16 vs 0.52 ± 0.13, $P < 0.001$) was associated with major adverse outcomes including congestive heart failure, reinfarction and mortality (22). Similarly, over a 2-year follow-up duration Hole *et al*. found that Tei index was a better predictor of major adverse outcome compared to baseline LVESI and EDT but Tei index was not a better predictor of heart failure or death (23). Rahman *et al*. found that a Tei index value >0.40 had better sensitivity (86% vs 65%), specificity (82% vs 50%) and accuracy (83% vs 58%) compared to LVEF <40% for predicting cardiac complications including cardiogenic shock, revascularisation, readmissions, congestive heart failure and advanced atrioventricular heart block (17).

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Table 3 Tei index cut off values, outcomes and prognostic use of Tei index.

Study ID	Tei index abnormal cut off values	Tei index and outcomes	Tei index prognostically useful?
Abuomara 2018	>0.73	Tei Index with and without heart failure: 0.88 ± 0.18 vs 0.58 ± 0.11, $P = 0.0001$. Heart failure with Tei Index >0.73: sensitivity 78.3%, specificity 94.6%.	Yes, able to predict development of heart failure
Biering-Sørensen 2013	0.59 ± 0.16	Tei Index with and without major adverse outcome: 0.59 ± 0.16 vs 0.52 ± 0.13, $P<0.001$.	Yes, able to predict development of heart failure, future hospitalisation, reinfarction and mortality
Hole 2003	N/A	Tei Index was a significant predictor of major adverse outcome, but not for the development of heart failure or death.	No, not able to predict heart failure episodes.
Karvounis 2004	N/A	Control vs Killip class I vs Killip class II and III: Tei Index at day 1: 0.330 ± 0.080 vs 0.344 ± 0.084 vs 0.686 ± 0.120, $P < 0.0001$. Tei Index At 1 month: 0.330 ± 0.080 vs 0.329 ± 0.080 vs 0.649 ± 0.110, $P < 0.0001$.	Yes, associated with mortality.
Møller 2001	>0.63	One-year survival in patients with Tei Index <0.63 was 89% compared to 37% in patients with index ≥0.63, $P < 0.0001$. Cardiac death with Tei Index >0.63: RR 5.6 (2.4–13.0), $P < 0.0001$.	Yes, able to predict LV dilatation and mortality.
Møller 2003	N/A	Multivariable predictors of all-cause deaths according to Tei index: Tei index < 0.46: ref. Tei index 0.46–0.55: aRR 2.1 (1.2–3.6), $P = 0.001$. Tei index 0.56–0.68: aRR 2.3 (1.5–3.9), $P = 0.001$. Tei index > 0.68: aRR 4.0 (2.1–11.6), $P < 0.0001$.	Yes, independent predictor of morality.
Rahman 2009	>0.40	Prediction of cardiac complications: Tie index of >0.40 sensitivity 86%, specificity 82%, accuracy 83%. Tei Index and hazards ratios for complications: Cardiogenic shock: HR 2.5 (1.7–3.6), $P = 0.008$. Cardiac death: HR 2.0 (1.4–2.9), $P = 0.30$. Revascularisation: HR 2.0 (1.6–2.7), $P = 0.023$. Readmission: HR 1.3 (1.1–1.4), $P = 0.016$. Congestive heart failure: HR 2.0 (1.6–2.7), $P = 0.041$. Secondary arrhythmias: HR 1.5 (1.1–1.9), $P = 0.32$. Advanced atrioventricular block: HR 1.4 (1.2–1.7), $P = 0.03$.	Yes, independent predictor of cardiac complications (excluding secondary arrhythmia's).
Sasao 2004	>0.70	Tei index significantly higher in acute myocardial infarction patient's vs controls: 0.630 vs 0.375, $P < 0.0001$. Tei index >0.70 was significantly correlated with cardiac events (cardiac death or congestive heart failure): OR 14.139 (1.269–157.553), $P = 0.0313$.	Yes, significantly associated with development of heart failure and mortality but only when LVEF <45% in patients >60 years.
Schwammenthal 2003	>0.52	Multivariable predictor of death, congestive heart failure and reinfarction: Tei Index ≥0.52: OR 1.09 (0.59–2.14). LVEF <40%: OR 3.82 (2.15–6.87).	No, not able to predict development of heart failure, reinfarction or mortality.
Souza 2011		Independent predictor of in-hospital congestive heart failure events: Left ventricular ejection fraction ≤45%: OR 17.0 (4.1–70.8), $P < 0.0001$. Age ≥60 and Tei index <0.57: OR 0.5 (0.1–4.1). Age ≥60 and Tei index ≥0.57: OR 13.7 (2.7–68.6), $P = 0.02$	Yes, independent predictor for development of in-hospital heart failure.

(*Continued*)

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Table 3 Continued.

Study ID	Tei index abnormal cut off values	Tei index and outcomes	Tei index prognostically useful?
Szymanski 2002	>0.55	Cardiac deaths and nonfatal recurrent myocardial infarction with Tei index >0.55 aRR 4.45 (1.28–15.45), $P = 0.019$.	Yes, independent predictor for mortality or reinfarction.
Uzunhasan 2006	Heart failure: >0.76 ± 0.27 Mortality: 0.60 ± 0.32	AMI patients ($n = 77$), controls ($n = 88$) High (>0.60) vs low (<0.60) Tei index: Death: 12 (30.8%) vs 1 (2.6%). Heart failure: 19 (48.7%) vs 3 (7.9%). Mean Tei index of surviving vs dead patients: 0.61 ± 0.1 vs 0.7 ± 0.1, $P = 0.001$.	Yes, indictor for development of heart failure, LV dysfunction and mortality.
Westholm 2013	N/A	ROC analysis with AUC for Tei Index SD vs Tei Index Delta vs Simpson LVEF in respect to death: 0.65 (0.56–0.74) vs 0.64 (0.55–0.73) vs 0.73 (0.65–0.81).	No, no significant prognostic information derived.
Yilmaz 2004	>0.60	Left ventricular thrombus formation prediction had a sensitivity of 81%, specificity of 73%, positive predictive value of 62%, negative predictive value of 88%.	Yes, able to predict development of LV thrombus.
Yuasa 2005	>0.59	Multivariate predictors of complications (left ventricular aneurysm, heart failure, shock, paroxysmal atrial fibrillation, cardiac death, ventricular tachycardia/ventricular fibrillation, pericardial effusion, cardiac rupture, advanced atrioventricular block).	Yes, able to predict complications of AMI.
Zamfir 2016	N/A	RV Tei index was the only parameter to correlated with major adverse cardiac events.	Yes, able to predict development of heart failure, reinfarction, need for re-vascularisation and mortality.

AUC, area under the curve; ROC, rceiver operating characteristics.

Westholm *et al*. found that Tei index did not have a better AUC for predicting adverse outcomes compared to Simpson's biplane LVEF (20). In the evaluation of left ventricular intra-cavity thrombus formation, Yilmaz *et al*. reported that a Tei index value >0.60 had good sensitivity (81%) and specificity (73%) and was significantly predictive of thrombus formation when compared to ejection fraction. Yuasa *et al*. found that the AUC analysis of a Tei index value ≥0.59 had similar AUC as ejection fraction <45% for 30-day complications (27). Zamfir *et al*. found that RV Tei index was the only parameter which significantly correlated with reinfarction, need for revascularisation and heart failure and death during the AMI hospitalisation (OR 9.17 95% CI 1.03–83.7) (29).

Discussion

Our review on Tei index and its predictive value in morbidity and mortality events in AMI patients have several key findings. First, several studies indicate that a greater Tei index value can predict morbidity and mortality events during both the initial hospitalisation period and follow-up period ranging from 30 days to 57 months. Second, there is no consistency of what constituents a greater, or abnormal, Tei index value. The most appropriate timing of Tei index evaluation is also not known. Thirdly, it is not certain whether the use of the Tei index has any advantage over the more utilised echocardiographic measurement of LVEF and the more recent addition of global longitudinal strain imaging. More studies are needed in order to better understand Tei index before its routine incorporation into every day clinical practice.

The studies included in this review had several key differences making it challenging to assess the prognostic value of Tei index in AMI patients. Suggesting an appropriate 'abnormal' cut off value for Tei index is challenging for a number of reasons. First, in this review, Tei index values were assessed at varying times throughout the initial hospitalisation period with differing 'abnormal' cut of values being applied. Even in the five studies (6, 19, 24, 26, 27), where Tei index was assessed within 24 h of AMI 'abnormal' Tei index 'abnormal' values ranged from >0.60 (27), 0.686 ± 0.12 (24), >0.70 (26), and >0.73 (6). Identifying an appropriate 'abnormal' Tei index cut

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off range in AMI patients is also further compounded by the fact that the original research, whereby a normal Tei index value of <0.39 ± 0.5 was derived, likely differs from the cohort of patients seen in this review. The original study by Tei *et al*. (1), was based on a cohort of 170 adult participants, 70 of which had a normal LVEF, whereas the remaining 100 participants were known to have a dilated cardiomyopathy of varying severities (LVEF ranging from 30 to 50%), the breakdown of the underlying pathology, however, is not clear. Future studies are needed to clarify the optimal timing for when Tei index should be assessed along with systematically determining a Tei index 'abnormal' cut off value which is best associated with adverse outcomes. The follow-up duration also varied vastly from the inclusion of the initial hospitalisation period only right up to 58 months post-AMI event. The use of different study end points was also apparent which included: mortality, reinfarction, left ventricular thrombus formation, tachyarrhythmia's, bradyarrhythmia's and heart failure episodes.

Current recommendations incorporate the use of LVEF and echocardiography assessment within 24–48 h of an AMI which enables patients to be risk-stratified and appropriately managed (9). Global longitudinal strain has also been shown to provide prognostic importance in AMI patients (30). However, the use of LVEF via Simpson's biplane and global longitudinal strain is reliant on adequate 2D endocardial border definition in non-foreshortened views. The Tei index is an easy measure of cardiac function which has the added advantage that it does not rely solely on adequate 2D image quality. This is important as Tei index could be used in patients where 2D/3D LVEF or global longitudinal strain are impossible due to poor endocardial definition. Furthermore, LVEF is hinder by inter and intraobserver variability, geometric assumptions, is pre and after-load dependent and is affected by the presence of variable and high heart rates (30). While there is limited evidence about the inter-observer variability of the Tei index measurements, the inter-observer variability is probably lower than that of either the left ventricular ejection fraction or global longitudinal strain measurements. Moreover, Tei index may be an attractive alternative quantification measurement as it has been shown to be independent of pre and after-load, heart rate and geometric assumptions (15). Thus, Tei index has the potential to be a more reproducible and reliable quantification measure with the added benefit of not being heavily reliance on the endocardial definition and adequate 2D image quality. The appropriate timing of Tei index remains unknown, it is also unsure of whether a higher Tei index value would be required if evaluation is performed within the first 24–48 h post-AMI.

This review highlights the potential importance of an 'abnormal' Tei index value and its prognostic benefit to patients which is in keeping with the known prognostic value of Simpson's biplane LVEF. There are some studies where the Tei index was found to be more sensitive, specific and accurate in comparison to LVEF in predicting morbidity and mortality events (6, 17, 27), however, each of these studies differed in terms of study end points, follow-up period as well as using differing Tei index cut off values. However, when a high Tei index was considered together with a reduced LVEF, there were studies to suggested Tei index does not yield additional prognostic information over LVEF alone. Nevertheless, when the LVEF was greater than 45% its prognostic value to predict adverse outcomes reliably is limited (31). The measurement of a 'abnormal' and high Tei index value in patients with mildly reduced or normal LVEF may highlight a previously undetected cohort of patients who are at a high risk of adverse events. Similarly, the finding of a reduced LVEF and low Tei index value may allow for further refinement in risk stratification of high-risk patients.

Studies have demonstrated myocardial recovery following an AMI event which can be easily detected with an improvement in Simpson's biplane LVEF (9). There is limited information on whether Tei index showed a similar improvement over time. Hole *et al*. and Karvounis *et al*. were the only two studies which assessed Tei index at baseline and follow-up the results of both indicated there to be no significant change. This was also irrespective of whether Tei index was high or not at baseline (23, 24). The clinical relevance of an improvement in Tei index over time remains unknown.

Karvounis *et al*. (24) was the only study to report on the individual components of Tei index. In this study, there was no change in the isovolumetric relaxation time at baseline and at one-month follow-up, this was irrespective of whether there were signs of heart failure or not in the included patient cohort. This study did not evaluate isovolumetric contraction.

This review highlights the small number of fair and good quality studies investigating Tei index in AMI patients. The strengths of the review are that it included only full studies with abstracts and case reports being excluded and all studies were prospective in design with well-defined patient outcome end points. Several studies included all coronary territory AMI events with only three studies being selective of anterior or anteroseptal AMI's.

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This enables the results to be more applicable to a wider patient cohort. In addition, the studies are representative of the AMI cohort that is seen in clinical practice with a male predominance. Limitations of this review include the small sample sizes with the largest study involving 417 patients, there were large variations in follow-up duration of patients. Patients were also managed differently which included being medically managed or receiving percutaneous coronary intervention which was performed either on admission or within 48 h of AMI event.

Several questions remain unanswered related to the role of Tei index in patients with AMI. Future large prospective studies should aim to determine an acceptable 'abnormal' cut off value for Tei index which is of a prognostic benefit to patients. The role of Tei index together with other measures such as 2D/3D LVEF and global longitudinal strain analysis in post-AMI patients merits further investigation over a short and long-term follow-up period. The importance of a greater high Tei index value in patients with mildly impaired or a normal LVEF and a low Tei index value in patients with moderate or severely impaired LVEF should be investigated. In addition, the prognostic value of right ventricular myocardial performance in AMI patients should also be evaluated.

In conclusion, the studies in the literature suggest that the Tei index has value in identifying patients who have a greater propensity for adverse events after AMI. However, more studies are needed to determine how Tei index should be used before its routine inclusion within the clinical practice as there is uncertainly to its additional value over well-established parameters such as LVEF.

Supplementary materials

This is linked to the online version of the paper at https://doi.org/10.1530/ERP-20-0017.

Declaration of interest

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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