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Impact of Left and Right Bundle Branch Block on Left Ventricular Systolic Function and Myocardial Mechanics Assessed by Speckle-Tracking Echocardiography and Cardiac Magnetic Resonance Feature Tracking: A Systematic Review and Meta-Analysis

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INTRODUCTION

Review question / Objective The present systematic review and meta-analysis aimed to comprehensively evaluate the available evidence regarding myocardial deformation abnormalities assessed by speckle tracking echocardiography (STE) and cardiac magnetic resonance feature tracking (CMR-FT) in patients with left bundle branch block (LBBB) and right bundle branch block (RBBB). Specifically, we sought to summarize the clinical and imaging characteristics of the included studies, assess the association between conduction abnormalities and myocardial strain impairment, and explore the prognostic implications of deformation imaging parameters across different bundle branch block phenotypes.

Rationale In recent years, both speckle tracking echocardiography (STE) and cardiac magnetic resonance feature tracking (CMR-FT) have been increasingly applied to characterize myocardial mechanics in patients with conduction abnormalities across different clinical settings, including heart failure, dilated cardiomyopathy, post-transcatheter aortic valve replacement (TAVR), and apparently isolated bundle branch block without overt structural heart disease. However, available studies remain heterogeneous in terms of imaging methodology, study design, analyzed strain parameters, patient populations, and reported clinical endpoints. Furthermore, the relative contribution of left- versus right-sided conduction delay to ventricular remodeling and prognostic stratification remains incompletely understood.

Condition being studied Left bundle branch block (LBBB) and right bundle branch block (RBBB) are common intraventricular conduction abnormalities associated with significant alterations in ventricular activation, myocardial mechanics, and clinical outcomes [1-3]. Although conventional electrocardiographic assessment remains the cornerstone for the diagnosis of bundle branch block patterns, increasing evidence suggests that electrical dyssynchrony does not necessarily correspond to the extent of underlying mechanical dysfunction [4,5]. In this context, advanced cardiac imaging modalities, particularly speckle tracking echocardiography (STE) and cardiac magnetic resonance feature tracking (CMR-FT), have emerged as valuable tools for the comprehensive assessment of myocardial deformation and ventricular dyssynchrony [6].

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METHODS

Search strategy A comprehensive literature search was independently performed by two investigators to identify studies evaluating myocardial mechanics, cardiac function, and deformation imaging abnormalities in patients with left bundle branch block (LBBB) and/or right bundle branch block (RBBB) using speckle tracking echocardiography (STE) and/or cardiac magnetic resonance feature tracking (CMR-FT).

Electronic databases including PubMed, Scopus, and EMBASE were systematically searched from database inception to May 2026. The search strategy combined Medical Subject Headings (MeSH) terms and free-text keywords related to conduction abnormalities, ventricular dyssynchrony, myocardial deformation, and cardiac mechanics. Search terms included combinations of “left bundle branch block”, “right bundle branch block”, “LBBB”, “RBBB”, “bundle branch block”, “conduction abnormalities”, “intraventricular conduction delay”, “cardiac mechanics”, “cardiac function”, “myocardial deformation”, “global longitudinal strain”, “GLS”, “global circumferential strain”, “GCS”, “global radial strain”, “GRS”, “right ventricular strain”, “mechanical dyssynchrony”, “speckle tracking echocardiography”, “2D-STE”, “3D-STE”, “cardiac magnetic resonance”, “CMR”, “feature tracking”, “CMR-FT”, “left ventricular ejection fraction”, and “right ventricular ejection fraction”.

No restrictions regarding publication year, geographic region, or language were applied. Additional potentially eligible studies were identified through manual screening of the reference lists of included articles and relevant review papers. Any disagreement during study selection was resolved by discussion and consensus, with involvement of a third reviewer when necessary.

Participant or population Patients with left bundle branch block (LBBB) and/or right bundle branch block (RBBB).

Intervention To evaluate differences in ventricular systolic function and myocardial deformation parameters among LBBB, RBBB, and control populations.

Comparator LBBB patients vs Ctrls, RBBB patients vs Ctrls, LBBB patients vs RBBB patients.

Study designs to be included Observational Cohort and Cross-Sectional Studies.

Eligibility criteria Studies were considered eligible if they had an observational design, including prospective cohorts, retrospective cohorts, or cross-sectional investigations, and evaluated myocardial deformation parameters and/or ventricular systolic function in adult patients with LBBB and/or RBBB using STE and/or CMR-FT techniques.

Eligible studies were required to report extractable quantitative imaging data regarding at least one of the following parameters: left ventricular ejection fraction (LVEF), left ventricular global longitudinal strain (LV-GLS), global circumferential strain (GCS), global radial strain (GRS), right ventricular global longitudinal strain (RV-GLS), right ventricular free-wall longitudinal strain (RV-FWLS), right ventricular ejection fraction (RVEF), or other deformation-derived markers of ventricular mechanics and dyssynchrony.

Studies including healthy control groups were considered eligible for quantitative meta-analysis. Investigations lacking a control population were retained for the systematic review and descriptive pooled analyses but were excluded from comparative meta-analytic synthesis.

Both echocardiographic and CMR-derived deformation analyses were considered eligible because the primary objective of the study was to comprehensively evaluate myocardial mechanics across different imaging modalities. Studies performed in pediatric populations, animal models, or experimental settings were excluded. Similarly, conference abstracts, editorials, reviews, case reports, expert opinions, and studies without sufficient quantitative imaging data were not considered eligible.

Information sources Electronic databases including PubMed, Scopus, and EMBASE were systematically searched from database inception to May 2026.

Main outcome(s) The primary quantitative analyses aimed to evaluate differences in ventricular systolic function and myocardial deformation parameters among LBBB, RBBB, and control populations. Separate meta-analyses were performed for LVEF and LV-GLS.

Additional outcome(s) N/A.

Data management Two investigators independently screened all retrieved studies by title and abstract, followed by full-text evaluation according to predefined inclusion and exclusion criteria. Disagreements regarding study eligibility were resolved through consensus discussion.

Data extraction was independently performed using a standardized collection form specifically developed for the present review. Extracted variables included first author, publication year, country, study design, imaging modality, software vendor, study population, sample size, and sex distribution.

Clinical variables included age, cardiovascular risk factors, atrial fibrillation prevalence, heart rate, blood pressure values, New York Heart Association (NYHA) class, renal function, natriuretic peptide levels, and ongoing medical therapies whenever available.

Conventional imaging parameters were systematically collected to characterize cardiac structure and function. These included left ventricular dimensions and volumes, LVEF, left atrial dimensions, E/A ratio, E/e′ ratio, systolic pulmonary artery pressure (sPAP), tricuspid annular plane systolic excursion (TAPSE), right ventricular dimensions, and ventricular volumetric parameters.

Deformation-derived imaging variables obtained by STE and/or CMR-FT were additionally extracted, including LV-GLS, LV-GCS, LV-GRS, RV-GLS, RV-FWLS, septal deformation patterns, myocardial work indices, mechanical dispersion, ventricular dyssynchrony parameters, late gadolinium enhancement (LGE), and extracellular volume fraction (ECV) whenever available.

Clinical endpoints including cardiovascular mortality, heart failure hospitalization, arrhythmic events, CRT response, ventricular remodeling, valve intervention outcomes, and composite major adverse cardiovascular events were systematically recorded.

For consistency and interpretability, strain parameters originally expressed as negative percentages were uniformly reported as absolute positive values throughout pooled analyses and tables without altering relative intergroup differences or statistical significance.

Quality assessment / Risk of bias analysis Methodological quality and risk of bias were independently assessed by two investigators using the National Institutes of Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [7].

This tool evaluates several methodological domains including study population definition, participant selection, exposure and outcome assessment, statistical methodology, confounding adjustment, reproducibility of measurements, and adequacy of follow-up.

Each study was evaluated across 14 predefined domains and classified as “Yes”, “No”, “Cannot Determine”, “Not Reported”, or “Not Applicable”. Overall study quality was categorized as good, fair, or poor according to the number of fulfilled criteria and the clinical relevance of methodological limitations. Disagreements between reviewers were resolved through joint reassessment until consensus was achieved.

Reference:
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Strategy of data synthesis To provide an overall descriptive characterization of the included populations, pooled study-level estimates were calculated using weighted descriptive statistics. Continuous variables were summarized as weighted means with weighted interquartile ranges (IQRs), using study sample size as weighting factor. Since most studies reported data as mean ± standard deviation, approximate pooled distributions were derived assuming near-normal distribution. These pooled estimates were intended for descriptive purposes rather than formal patient-level inferential analyses. Accordingly, exploratory p values should be interpreted cautiously.

The primary quantitative analyses aimed to evaluate differences in ventricular systolic function and myocardial deformation parameters among LBBB, RBBB, and control populations. Separate meta-analyses were performed for LVEF and LV-GLS. Specifically, six independent comparative meta-analyses were conducted: (1) LVEF in LBBB versus controls, (2) LVEF in RBBB versus controls, (3) LVEF in LBBB versus RBBB, (4) LV-GLS in LBBB versus controls, (5) LV-GLS in RBBB versus controls, and (6) LV-GLS in LBBB versus RBBB.

For each meta-analysis, studies were a priori stratified according to the imaging modality used for myocardial functional assessment, namely speckle-tracking echocardiography (STE) and cardiac magnetic resonance feature tracking (CMR-FT). Separate pooled effect estimates (subtotal analyses) were first calculated within each imaging modality subgroup. Subsequently, an overall pooled estimate was derived by combining all eligible studies irrespective of imaging modality. This hierarchical approach allowed assessment of both modality-specific effects and overall differences between study populations, while also permitting formal evaluation of between-subgroup heterogeneity according to imaging technique.

Comparative pooled analyses were conducted using standardized mean differences (SMDs) with corresponding 95% confidence intervals (CIs). Fixed-effects or random-effects models were selected according to the degree of between-study heterogeneity. Specifically, fixed-effects models were applied in the presence of negligible heterogeneity ($I^2 = 0\%$), whereas random-effects models based on the DerSimonian–Laird method were used when heterogeneity was moderate or high.

Statistical heterogeneity was assessed using Cochran's Q statistic and quantified using the I^2 index. For each meta-analysis, heterogeneity was evaluated both within individual imaging modality subgroups (STE and CMR-FT) and across the overall pooled model. In addition, between-subgroup heterogeneity was assessed using the Q-between statistic to determine whether the magnitude of the observed effect differed according to imaging modality. I^2 values of approximately 25%, 50%, and 75% were considered indicative of low, moderate, and high heterogeneity, respectively.

Sensitivity analyses using a leave-one-out approach were performed whenever appropriate to assess the robustness of pooled estimates.

Publication bias and small-study effects were evaluated through visual inspection of funnel plots and Egger's regression asymmetry test when a sufficient number of studies was available. Funnel plot analyses and meta-regression models were not performed in meta-analyses including only two studies because of the limited statistical reliability and interpretability of these approaches in very small datasets.

Meta-regression analyses were performed only in the presence of an adequate number of studies and clinically meaningful heterogeneity. Potential moderators included age, sex distribution, imaging modality, and software vendor whenever sufficient data were available.

All statistical analyses were performed using Comprehensive Meta-Analysis software (version 3.0; Biostat, Englewood, NJ, USA).

Subgroup analysis STE studies (Subgroup 1) and CMR-FT studies (Subgroup 2).

Sensitivity analysis Sensitivity analyses using a leave-one-out approach were performed whenever appropriate to assess the robustness of pooled estimates.

Language restriction No language restriction.

Country(ies) involved Italy.

Keywords left bundle branch block; right bundle branch block; conduction abnormalities; cardiac mechanics; cardiac function; speckle-tracking echocardiography; cardiac magnetic resonance; myocardial.

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