Effects of SGLT2 inhibitors on right ventricular function in heart failure patients: Updated meta-analysis of the current literature

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ABSTRACT

Background: There is some discrepancy in current studies concerning the effect of sodium-glucose cotransporter type 2 inhibitors (SGLT2i) on right ventricular (RV) functions in heart failure (HF) patients. Hence, this meta-analysis was focused on determining the impact of SGLT2i on RV functions in such individuals.

Material and methods: Two independent investigators searched PubMed, Google Scholar, and the Cochrane Library for articles of interest. To analyze heterogeneity, Higgins' I^2 as well as prediction intervals and Egger's test were used to assess heterogeneity. The Newcastle–Ottawa standard ratings approach was used to assess the quality of observational studies. The ROBINS-I risk of bias algorithm was used to assess bias risks of randomized studies.

Results: This meta-analysis evaluated 8 studies in total. Over the follow-up time frame, patients who used SGLT2i had substantially lower systolic pulmonary artery pressure and higher tricuspid annular plane systolic excursion values (mean difference [MD] = –5.23 [–7.81; –2.66] and, MD = 1.47 [1.01; 1.93]; P <0.01, respectively). There was no significant difference in RVS' values between follow-up and baseline (MD = 1.54 [–0.19; 3.26]; P = 0.08). However, as compared to the baseline period, fractional area contraction values were substantially larger at the end of the follow-up (MD = 5.52 [4.23; 6.82]; P <0.01).

Conclusion: To the best of our knowledge, this is the first meta-analysis assessing the impact of SGLT2i on RV function in HF patients. Our findings suggest that SGLT2i may improve RV performance in HF patients.

Key words: heart failure, meta-analysis, right function, SGLT2i

INTRODUCTION

Heart failure (HF) is defined as a chronic inflammatory disease that presents with characteristic symptoms and signs that lower the quality of life while increasing mortality and morbidity risk [1]. Right ventricular (RV) dysfunction is commonly observed in HF individuals in addition to left ventricular (LV) dysfunction [1]. Right ventricular HF (RVHF) can occur as a result of a variety of processes that precede left ventricular HF (LVHF). Pathologies that could contribute to LVHF, such as ischemia, cardiomyopathies, or myocarditis, can also impact RVHF the development of RVHF. Elevated systolic pulmonary artery pressure (sPAP), which develops in LVHF, raises the afterload against which the RV must pump [2]. Severe LVHF can compromise RV diastolic performance by increasing RV dilation and pericardial restriction, resulting in reduced

WHAT'S NEW?

Studies on the effect of sodium-glucose cotransporter type 2 inhibitors (SGLT2i) on right ventricular functions in heart failure patients are inconsistent. During the follow-up period, SGLT2i significantly reduced systolic pulmonary artery pressure and increased tricuspid annular plane systolic excursion values, as well as fractional area contraction values. Our meta-analysis suggests that SGLT2i may enhance right ventricular functions in individuals with heart failure.

coronary perfusion [1]. Notably, previous research demonstrated that RVHF is the most important predictor of a poor outcome in HF [2, 3].

Sodium-glucose cotransporter type 2 inhibitors (SGLT2i) act by preventing sodium and glucose reabsorption from the kidney's proximal tubules [4, 5]. This process indirectly influences many pathways, resulting in a variety of consequences in the body, including decreased vascular inflammation, generation of reactive oxygen species, and improved endothelial function via lowering vascular stiffness [1, 2]. Randomized controlled studies have been conducted in recent years to investigate the impact of SGLT2i in HF patients [2, 6]. These studies found that SGLT2i lower cardiovascular mortality, all-cause mortality, and hospitalization in HF patients with and without diabetes. On the other hand, few studies examined the effects of SGLT2i on RV function. Although some research shows that SGLT2i have a favorable effect on RV functioning, other studies did not show substantial findings [1, 6, 7]. As a result, the goal of this meta-analysis was to investigate whether SGLT2i might have any effect on RV functioning.

MATERIAL AND METHODS

Data collection

This meta-analysis was performed in accordance with the Cochrane Collaboration's standards. The subsequent keywords were applied to search PubMed, Google Scholar, and the Cochrane Library to search for eligible articles: "sodium-glucose cotransporter-2 (SGLT2) inhibitors, SGLT2 inhibitors, heart failure, right heart, right heart function, effect of SGLT2 inhibitors on right heart, effect of SGLT2 inhibitors on right heart failure, SGLT2 inhibitors on Tricuspid Annular Plane Systolic Excursion (TAPSE), SGLT-2 inhibitor TAPSE, SGLT2 inhibitors on systolic pulmonary artery pressure, SGLT2 inhibitors on sPAP, SGLT2 inhibitors on RV". There were 98 articles available for evaluation. We also removed 75 irrelevant or duplicated articles, as well as case series and review articles by assessing their titles and abstracts and reserved 23 for full-text assessment. After studying their full texts, we left out 15 articles from this meta-analysis because of inappropriate designs, insufficient information to estimate impact size, and no reported outcomes of interest (Figure 1). Lastly, we finalized our analysis with the final 8 research articles (Table 1). The review methods in this meta-analysis were established before the conduct of the review with the protocol number CRD42023493377, and they were registered in the PROSPERO database.

Analysis of studies

Two independent investigators systematically reviewed all research articles for their relevance and bias probability. We applied the following criteria to analyze the articles: 1) studies that evaluated the effect of SGLT2 on right heart functions, 2) studies that presented data regarding baseline right heart functions, and 3) studies that published follow-up data. Furthermore, we excluded articles where the effect value and standard error could not be quantified. There were no strict limitations on study design and sample size, language, or follow-up duration.

Quality assessment and data extraction

All articles that met the inclusion criteria were evaluated by two independent authors, with a third author resolving any disagreements between them. Regarding the observational cohort studies included in this evaluation, the Newcastle-Ottawa standard rating method was implemented in evaluating their quality. According to this rating scale, a study can receive up to 9 points depending on the participant population, uniformity, and results of interest. Based on this scale, a score of 0 to 5 denotes low quality, whereas a score of 6 to 9 excellent quality. ROBINS-I and RoB-2 risk of bias algorithms based on the *Cochrane Handbook for Systematic Reviews* were applied in evaluating bias risks of randomized and observational investigations, respectively.

Clinical endpoints

This meta-analysis aimed to determine the effects of SGLT2i on RV functions in HF patients based on four echocardiographic parameters of RV functions including, TAPSE, sPAP, RVS', and fractional area change (FAC).

Statistical analysis

This meta-analysis was carried out using R statistical software, version 4.0.2 (Institute for Statistics and Mathematics in Vienna, Austria). A "meta" package with "metagen" was used for calculations of pooled mean differences between two time points for outcomes with 95% confidence intervals. The heterogeneity was calculated using Higgins's I^2, and I^2 <25% was accepted as low heterogeneity, whereas >75% as high. Since heterogeneity for all outcomes was over 25%, a random effect estimate was used for the calculation of pooled effect size. Additionally, prediction intervals and the Cochrane Q test were used to evaluate heterogeneity. Since baseline and follow-up values for all outcomes were obtained from the same individuals, that makes them repeated and correlated measures. Based on the *Cochrane Handbook*

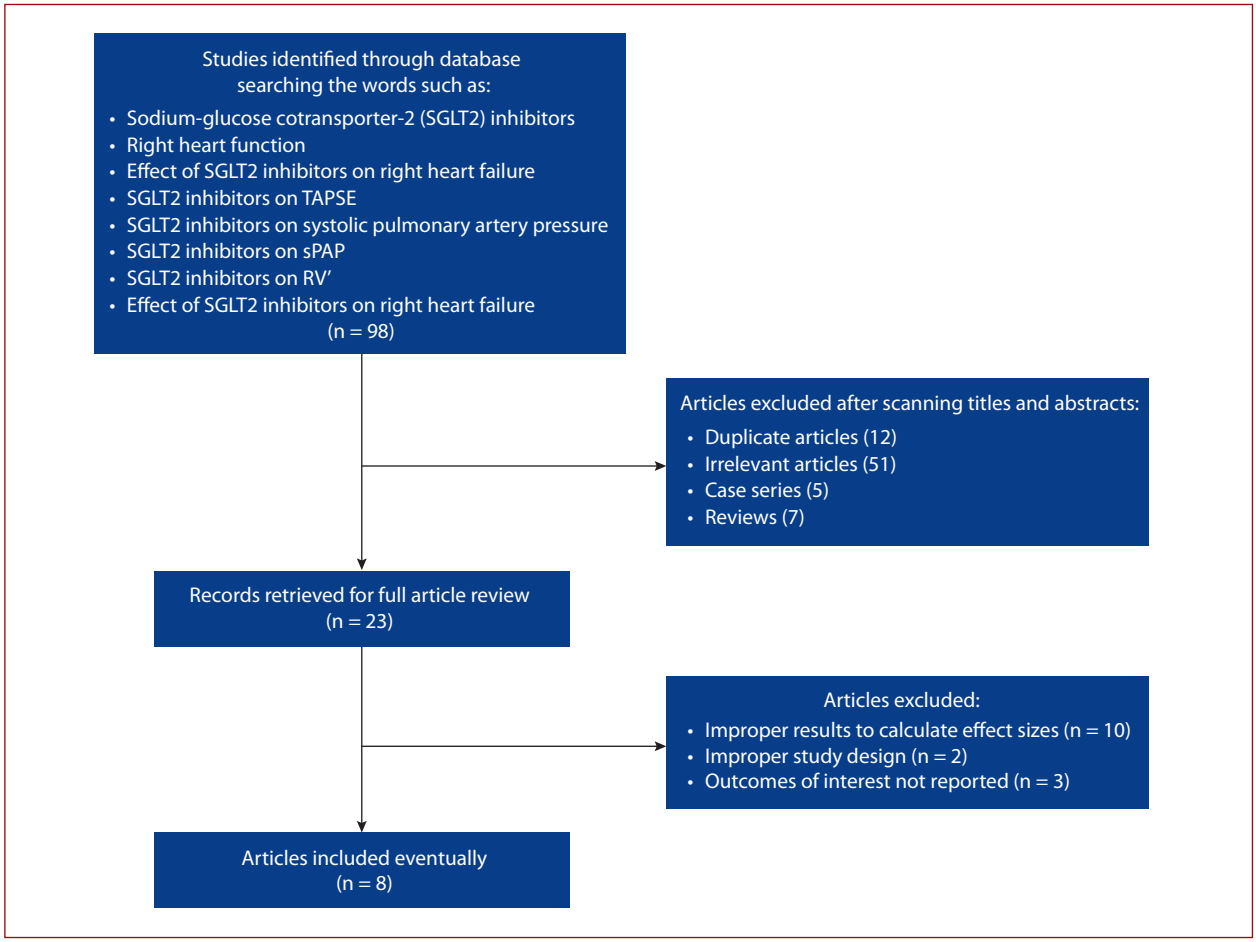

Figure 1. A flow diagram of meta-analysis

Abbreviations: RV, right ventricle; SGLT2, sodium-glucose cotransporter type 2; sPAP, systolic pulmonary artery pressure; TAPSE, tricuspid annular plane systolic excursion

Table 1. Studies included in the analysis

Study	Year	Country	Study sample	Age	Male sex	SGLT2 type	Time points	Study outcomes	Study design	Quality
Çamcı et al., 2022 [1]	2022	Turkey	168	62.7 (11.4)	77.4%	ALL	0–6 months	TAPSE, sPAP, RVS', FAC	Retrospective observational study	6
SIMPLE trial, 2022 [6]	2020	Denmark	17	65 (9)	61%	EMPAGLİ-FLOZİN	0–13 week	sPAP	RCT	7
Patoulias et al., 2022 [8]	2021	Greece	20	62.8 (7.87)	75%	ALL	0–6 months	TAPSE, RVS'	Prospective observational study	6
Mullens et al., 2020 [9]	2019	Belgium	9	72 (10)	NA	DAPAGLİ-FLOZİN	0–1 week	sPAP	Prospective observational study	5
Mustapic et al., 2022 [2]	2023	Croatia	18	67.3 (11.5)	88.9%	ALL	0–3 months	TAPSE, sPAP, RVS', FAC	Prospective observational study	6
Kirschbaum et al., 2022 [10]	2022	Germany	17	67.18 (3.09)	100%	ALL	0–10 week	sPAP	Prospective observational study	6
Correale et al., 2023 [11]	2023	Italy	38	65 (7)	89%	ALL	0–3 months	TAPSE, sPAP	Prospective observational study	6
Kotinas et al., 2023 [7]	2021	Italy	83	65.78 (8.53)	73.3%	ALL	0–12 months	TAPSE, RVS'	Retrospective observational study	6

Abbreviations: FAC, fractional area change; RCT, randomized controlled trial; other — see Figure 1

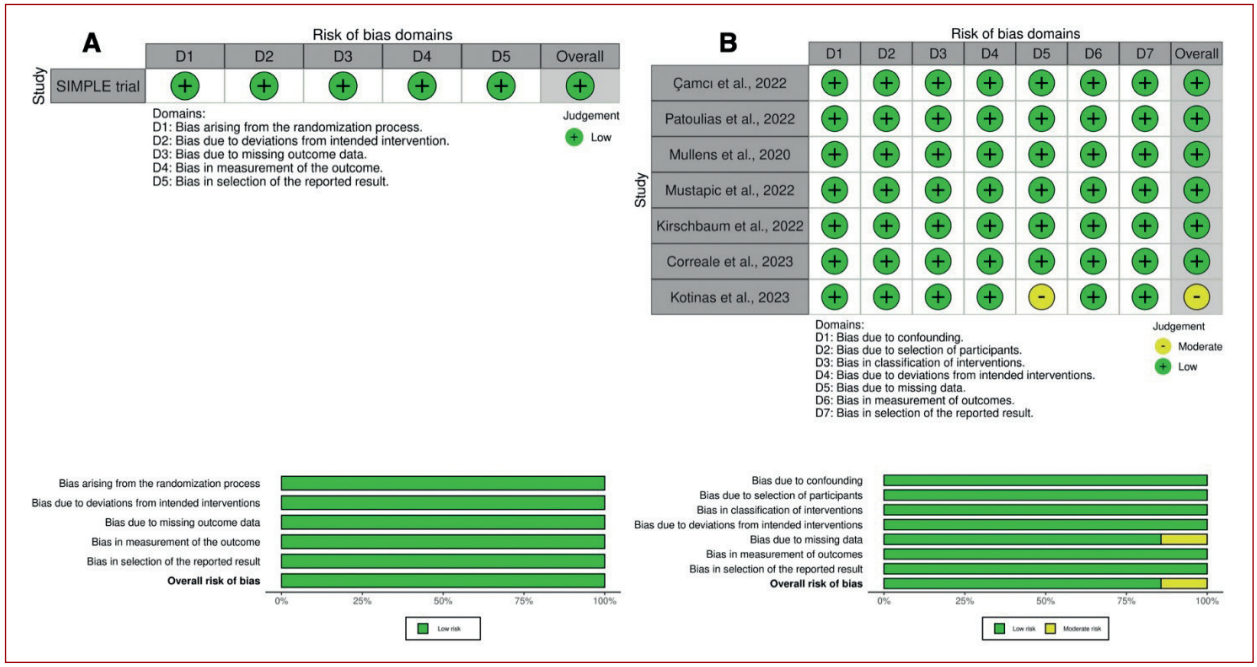

Figure 2. ROBIN-I (**A**) and ROB-2 (**B**) tools for assessing the risk of bias for randomized and observational studies in the meta-analysis, respectively

for Systematic Reviews of Interventions, an r (correlation coefficient) value can be calculated from baseline standard deviation (SD), follow-up SD, and also mean difference SD from the formulae; $r = (SD^2_{baseline} + SD^2_{follow\text{-}up} + SD^2_{mean\text{-}difference})/(2 \times SD_{baseline} \times SD_{follow\text{-}up})$. However, all studies reported a mean difference between follow-up and baseline values and none of them reported SD of mean difference. Thus, we could not calculate the r value from at least one study to apply it to all remaining studies, which was recommended by the Cochrane Handbook as an alternative method. Another approach that was recommended by the Cochrane Handbook was to choose a hypothetical r value. Therefore, we used an r value of 0.7 and also performed sensitivity analysis based on 0.1 and 0.9 values. The results of sensitivity analyses for all outcomes are summarized in the Supplementary material, *Table S1*. Alternatively, it is proposed to apply a robust variance estimation method for estimating correlated effect size and variances, in which the r value is unknown. Thus, we also calculated effect size and 95% confidence intervals based on the robust variance estimation method and added those values in the Supplementary material, *Table S1* too. Finally, our results were robust for different r values and were consistent with the results of the robust variance estimation method as demonstrated in the Supplementary material, *Table S1*.

Since the number of studies included in this meta-analysis was <10, we could not perform meta-regression to detect the underlying cause of heterogeneity between studies. Although funnel plots to evaluate for potential publication bias do not give precise estimation in the setting of the small number of studies (n <10) in our meta-analysis, we created funnel plots for all outcomes to assess the potential publication bias. There were potential publication biases for all outcomes except sPAP (Supplementary material, *Figure S1*). However, due to the low number of studies, these results are unlikely to be accurate. A *P*-value of 0.05 was used to determine statistical significance (2-tailed tests).

RESULTS

This meta-analysis included 1 randomized controlled trial and 6 prospective and 1 retrospective observational studies consisting of 370 patients. The majority of patients in the study population were male, and the mean (SD) age was 64.3 (9.9) [1, 2, 6, 8–11]. In terms of bias, both randomized controlled trials (Figure 2A) and observational studies (Figure 2B) had a low risk of bias except for one prospective observational study conducted by Kotinas et al. [7], which had a moderate risk of bias due to the higher rates of missing values in the follow-up. In most of the studies, no specific SGLT2i was investigated.

Regarding evaluating right heart functions, TAPSE values of patients who used SGLT2i were significantly elevated during the follow-up period (mean difference [MD] = 1.47 [1.01; 1.93]; *P* <0.01). Notably, although patients on SGLT2i had lower sPAP values after the follow-up when compared to the baseline values (MD = –5.23 [–7.81; –2.66]; *P* <0.01), there was high heterogeneity (84%) and wide prediction interval (–13.11; 2.64), which indicates that this result requires confirmation in further meta-analyses with more studies. There was no difference between follow-up and baseline values with respect to RVS' values (MD = 1.54 [–0.19; 3.26]; *P* = 0.08). FAC values were significantly higher at the end of the follow-up compared to the baseline period (MD = 5.52 [4.23; 6.82]; *P* <0.01) (Figure 2).

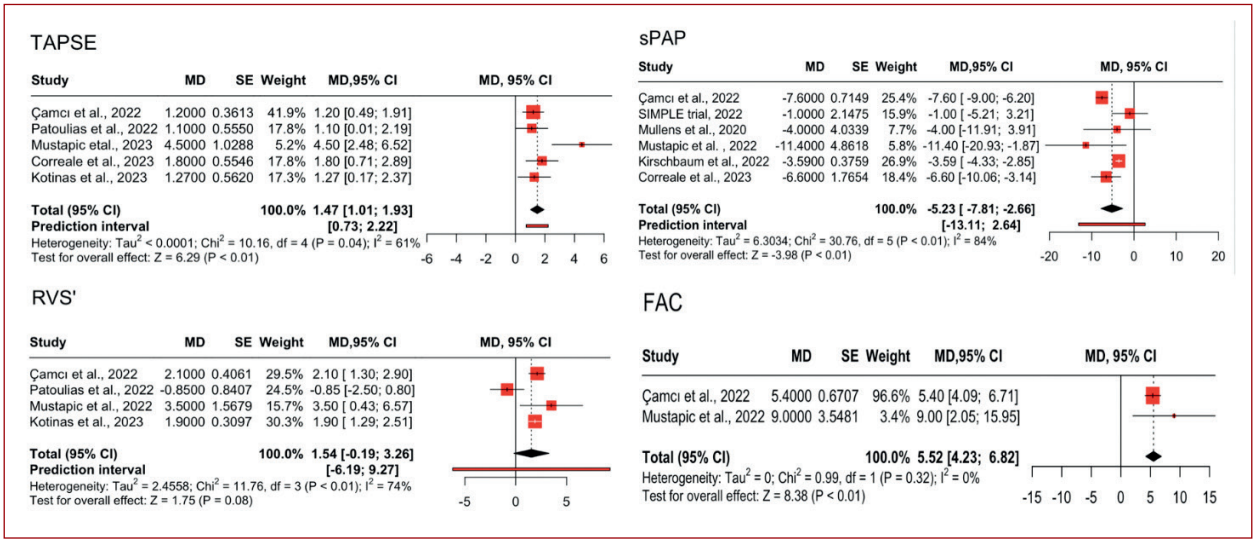

Figure 3. The pooled effect of SGLT2 inhibitors on TAPSE, RVS', sPAP, and FAC

Abbreviations: see Table 1

DISCUSSION

To the best of our knowledge, the current meta-analysis is the first to show that SGLT2i improve RV functions based on TAPSE, sPAP, and FAC values. Our results highlight the potential beneficial impact of SGLT2i on HF patients with RV dysfunctions.

Randomized studies have shown that SGLT2i can reduce all-cause mortality and hospital admissions in HFRV patients [12, 13]. Dysfunction is an important indicator of HF progression and poor prognostic outcomes [14]. In the same way, an improvement in RV function is associated with favorable outcomes in HF patients [15]. Hence, enhancing RV functions is a key objective in the treatment of HF patients.

SGLT2i exert their beneficial effects through various mechanisms [4]. Multiple pleiotropic mechanisms beyond glycemic control are thought to be responsible for the benefits of SLGT2 inhibitors in HF [16]. The benefits encompass natriuresis and a decrease in plasma volume, enhanced oxygen-carrying capability, and improved supply of oxygen to tissues due to an elevation in hematocrit. Possessing robust antioxidant and anti-inflammatory characteristics, they enhance endothelium-dependent vasodilation by increasing the bioavailability of nitric oxide produced by the endothelium [17, 18]. They also show their positive effects by decreasing glomerular pressure and oxygen consumption in the proximal tubules of the kidneys, modulating Na+/H+ exchange in the heart and kidneys and adipokine production [19, 20]. SGLT2i induce a significant shift in myocardial metabolism, transitioning from reliance on glucose to usage of fatty acids, ketone bodies, and branched-chain amino acids. This shift results in augmentation of myocardial energy [21]. An alternative hypothesis suggests that in individuals with diabetes, SGLT2i in the proximal tubule may favorably affect the heart *via* a steep Frank-Starling curve driven by natriuresis and glycosuria [19]. Each beneficial SGLT2i effect can be considered as a mechanism that contributed to the improvement of RV function shown in our meta-analysis.

SGLT2i have been shown to provide a significant improvement in pulmonary artery stiffness (PAS) and RV systolic function compared to baseline as measured by TAPSE and FAC in HF patients [22]. Another study in HF patients with the CardioMEMS pulmonary artery pressure (PA) sensor showed that empagliflozin caused rapid decreases in PA pressures, independent of loop diuretic administration. Our study suggests that mechanisms beyond the diuretic effect of the SGLT2i in HF contribute to the observed reductions in PA pressures. SGLT2i may lower PA pressures by positively impacting endothelial functions, primarily through their vasodilator effect on nitric oxide [23]. In addition, the initial volume reduction by the effect of osmotic diuresis causes a decrease in lung pressure [4]. Elevated PA pressures are indicative of impending HF symptoms, unplanned hospital admissions, and increased mortality [24, 25]. A study in 168 HF patients showed that SGLT2i resulted in positive changes in RV function and sPAS, as well as symptomatic and functional well-being [1]. Reducing PAS provides better pulmonary vascular compliance, alleviates RV afterload, and ultimately improves RV systolic function. In addition, the previously demonstrated reduction in LV filling pressure and improvement in diastolic function caused by SGLT2i may also be considered to contribute to the improvement in RV function [26]. The addition of SGLT2i to optimal medical therapy significantly reduces the degree of tricuspid regurgitation compared to optimal medical treatment alone [2].

When we searched the current literature, we could not find any meta-analysis that examined the effects of SGLT2i on RV functions in HF patients. To our knowledge, this might be the first meta-analysis on this topic. We also think that, based on our meta-analysis findings, more large

prospective and longitudinal studies are needed to demonstrate the beneficial effects of SGLT2i on RV functioning.

Limitations

There are certain limitations to our meta-analysis. This meta-analysis evaluated a small number of studies with a limited sample size. However, we incorporated all of the studies to ensure more accurate outcomes. It is worth noting that the majority of the participants were male, which might be significant because RV function differs across sexes. Also, the majority of the studies had a relatively short follow-up period. Furthermore, most studies lacked right heart catheterization or cardiac magnetic resonance imaging to measure RV functioning, which might have influenced our findings. We were unable to do further analyses such as funnel plots and meta-regression since our meta-analysis comprised only 8 articles. Despite these significant limitations, our findings should encourage additional studies to determine the exact effects of SGLT2i on RV function and its prognostic relevance in HF patients.

CONCLUSION

This meta-analysis indicates some favorable effects of SGLT2i on RV function including TAPSE, PAP, and FAC in HF patients.

Supplementary material

Supplementary material is available at https://journals.viamedica.pl/polish_heart_journal.

Article information

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REFERENCES

1. Çamcı S, Yılmaz E. Effects of sodium-glucose co-transporter-2 inhibition on pulmonary arterial stiffness and right ventricular function in heart failure with reduced ejection fraction. Medicina (Kaunas). 2022; 58(8), doi: 10.3390/medicina58081128, indexed in Pubmed: 36013595.
2. Mustapic I, Bakovic D, Susilovic Grabovac Z, et al. Impact of SGLT2 Inhibitor Therapy on Right Ventricular Function in Patients with Heart Failure and Reduced Ejection Fraction. J Clin Med. 2022; 12(1), doi: 10.3390/jcm12010042, indexed in Pubmed: 36614843.
3. de Groote P, Millaire A, Foucher-Hossein C, et al. Right ventricular ejection fraction is an independent predictor of survival in patients with moderate heart failure. J Am Coll Cardiol. 1998; 32(4): 948–954, doi: 10.1016/s0735-1097(98)00337-4, indexed in Pubmed: 9768716.
4. Nassif ME, Qintar M, Windsor SL, et al. Empagliflozin effects on pulmonary artery pressure in patients with heart failure: results from the EMBRACE-HF trial. Circulation. 2021; 143(17): 1673–1686, doi: 10.1161/CIRCULATIONAHA.120.052503, indexed in Pubmed: 33550815.
5. Stompór T, Winiarska A. Kidneys in heart failure: impact of flozins. Kardiol Pol. 2023; 81(11): 1071–1080, doi: 10.33963/v.kp.97844, indexed in Pubmed: 37937356.
6. Wolsk E, Jürgens M, Schou M, et al. Randomized Controlled Trial of the Hemodynamic Effects of Empagliflozin in Patients With Type 2 Diabetes at High Cardiovascular Risk: The SIMPLE Trial. Diabetes. 2022; 71(4): 812–820, doi: 10.2337/db21-0721, indexed in Pubmed: 35061894.
7. Kotinas A, Gitto M, Terzi R, et al. 617 Effects of SGLT2 inhibitors on left and right ventricular function in a real-world diabetic population. Eur Heart J Suppl. 2021; 23(Supplement_G), doi: 10.1093/eurheartj/suab139.018.
8. Patoulias D, Toumpourleka M, Katsimardou A, et al. Effect of sodium-glucose co-transporter-2 inhibitors on right ventricular function in patients with type 2 diabetes mellitus: a pilot study. Kardiol Pol. 2022; 80(6): 696–698, doi: 10.33963/KP.a2022.0104, indexed in Pubmed: 35445742.
9. Mullens W, Martens P, Forouzan O, et al. Effects of dapagliflozin on congestion assessed by remote pulmonary artery pressure monitoring. ESC Heart Fail. 2020; 7(5): 2071–2073, doi: 10.1002/ehf2.12850, indexed in Pubmed: 32588973.
10. Kirschbaum K, Vasa-Nicotera M, Zeiher AM, et al. SGLT2 inhibitor therapy and pulmonary artery pressure in patients with chronic heart failure-further evidence for improved hemodynamics by continuous pressure monitoring. Clin Res Cardiol. 2022; 111(4): 469–472, doi: 10.1007/s00392-021-01954-4, indexed in Pubmed: 34689229.
11. Correale M, Mazzeo P, Fortunato M, et al. Switch to gliflozins and biventricular function improvement in patients with chronic heart failure and diabetes mellitus. Clin Physiol Funct Imaging. 2024; 44(1): 112–117, doi: 10.1111/cpf.12857, indexed in Pubmed: 37795627.
12. Anker SD, Butler J, Filippatos G, et al. Empagliflozin in heart failure with a preserved ejection fraction. N Engl J Med. 2021; 385(16): 1451–1461, doi: 10.1056/NEJMoa2107038, indexed in Pubmed: 34449189.
13. Solomon SD, McMurray JJV, Claggett B, et al. Dapagliflozin in heart failure with mildly reduced or preserved ejection fraction. N Engl J Med. 2022; 387(12): 1089–1098, doi: 10.1056/NEJMoa2206286, indexed in Pubmed: 36027570.
14. Carluccio E, Biagioli P, Alunni G, et al. Prognostic value of right ventricular dysfunction in heart failure with reduced ejection fraction: superiority of longitudinal strain over tricuspid annular plane systolic excursion. Circ Cardiovasc Imaging. 2018; 11(1): e006894, doi: 10.1161/CIRCIMAGING.117.006894, indexed in Pubmed: 29321212.
15. Dini FL, Carluccio E, Simioniuc A, et al. Network Labs Ultrasound (NEBULA) in Heart Failure Study Group. Right ventricular recovery during follow-up is associated with improved survival in patients with chronic heart failure with reduced ejection fraction. Eur J Heart Fail. 2016; 18(12): 1462–1471, doi: 10.1002/ejhf.639, indexed in Pubmed: 27647757.
16. Verbrugge FH, Martens P, Mullens W. SGLT-2 inhibitors in heart failure: implications for the kidneys. Curr Heart Fail Rep. 2017; 14(4): 331–337, doi: 10.1007/s11897-017-0345-9, indexed in Pubmed: 28667491.
17. Durante W, Behnammanesh G, Peyton KJ. Effects of sodium-glucose co-transporter 2 inhibitors on vascular cell function and arterial remodeling. Int J Mol Sci. 2021; 22(16), doi: 10.3390/ijms22168786, indexed in Pubmed: 34445519.
18. Juni RP, Al-Shama R, Kuster DWD, et al. Cardiac microvascular endothelial enhancement of cardiomyocyte function is impaired by inflammation and restored by empagliflozin. JACC Basic Transl Sci. 2019; 4(5): 575–591, doi: 10.1016/j.jacbts.2019.04.003, indexed in Pubmed: 31768475.
19. Verma S, McMurray JJV. SGLT2 inhibitors and mechanisms of cardiovascular benefit: a state-of-the-art review. Diabetologia. 2018; 61(10): 2108–2117, doi: 10.1007/s00125-018-4670-7, indexed in Pubmed: 30132036.
20. Packer M. SGLT2 inhibitors produce cardiorenal benefits by promoting adaptive cellular reprogramming to induce a state of fasting mimicry: a paradigm shift in understanding their mechanism of action. Diabetes Care. 2020; 43(3): 508–511, doi: 10.2337/dci19-0074, indexed in Pubmed: 32079684.
21. Santos-Gallego CG, Requena-Ibanez JA, San Antonio R, et al. Empagliflozin ameliorates adverse left ventricular remodeling in nondiabetic heart failure by enhancing myocardial energetics. J Am Coll Cardiol. 2019; 73(15): 1931–1944, doi: 10.1016/j.jacc.2019.01.056, indexed in Pubmed: 30999996.
22. Sarak B, Verma S, David Mazer C, et al. Impact of empagliflozin on right ventricular parameters and function among patients with type 2 diabetes. Cardiovasc Diabetol. 2021; 20(1): 200, doi: 10.1186/s12933-021-01390-8, indexed in Pubmed: 34607574.

23. Uthman L, Homayr A, Juni RP, et al. Empagliflozin and dapagliflozin reduce ROS generation and restore NO bioavailability in tumor necrosis factor α-Stimulated human coronary arterial endothelial cells. Cell Physiol Biochem. 2019; 53(5): 865–886, doi: 10.33594/000000178, indexed in Pubmed: 31724838.
24. Bursi F, McNallan SM, Redfield MM, et al. Pulmonary pressures and death in heart failure: a community study. J Am Coll Cardiol. 2012; 59(3): 222–231, doi: 10.1016/j.jacc.2011.06.076, indexed in Pubmed: 22240126.
25. Zile MR, Bennett TD, St John Sutton M, et al. Transition from chronic compensated to acute decompensated heart failure: pathophysiological insights obtained from continuous monitoring of intracardiac pressures. Circulation. 2008; 118(14): 1433–1441, doi: 10.1161/CIRCULATIONAHA.108.783910, indexed in Pubmed: 18794390.
26. Lan NSR, Fegan PG, Yeap BuB, et al. The effects of sodium-glucose cotransporter 2 inhibitors on left ventricular function: current evidence and future directions. ESC Heart Fail. 2019; 6(5): 927–935, doi: 10.1002/ehf2.12505, indexed in Pubmed: 31400090.