

Comparison of the Effects of Glucagon-Like Peptide Receptor Agonists and Sodium-Glucose Co-Transporter 2 Inhibitors for Prevention of Major Adverse Cardiovascular and Renal Outcomes in Type 2 Diabetes Mellitus: A Systematic Review and Meta-Analysis of Cardiovascular Outcomes Trials

Running Title: *Zelniker et al.; Meta-Analysis of GLP1-RA and SGLT2i in T2DM*

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Abstract

Background: Glucagon-like peptide 1 receptor agonists (GLP1-RA) and sodium-glucose cotransporter-2 inhibitors (SGLT2i) have emerged as two new classes of antihyperglycemic agents that also reduce cardiovascular risk. The relative benefits in patients with and without established atherosclerotic cardiovascular disease (ASCVD) for different outcomes with these classes of drugs remain undefined.

Methods: We performed a systematic review and trial-level meta-analysis of GLP1-RA and SGLT2i cardiovascular outcomes trials using the PubMed and EMBASE databases. The primary outcomes were: the composite of myocardial infarction, stroke, and cardiovascular death (MACE); hospitalization for heart failure (HHF); and progression of kidney disease.

Results: In total, data from 8 trials and 77,242 patients, 42,920 (55.6%) in GLP1-RA trials and 34,322 (44.4%) in SGLT2i trials, were included. Both drug classes reduced MACE in a similar magnitude with GLP1RA reducing the risk by 12% (HR 0.88, 95%-CI 0.84 to 0.94; $p<0.001$) and SGLT2i by 11% (HR 0.89, 95%-CI 0.83 to 0.96; $p=0.001$). For both drug classes, this treatment effect was restricted to a 14% reduction in those with established ASCVD (HR 0.86, 95%-CI 0.80 to 0.93, $P=0.002$) whereas no effect was seen in patients without established ASCVD (HR 1.01, 95%-CI 0.87 to 1.16, $P=0.81$; p -interaction 0.028). SGLT2i reduced HHF by 31% (HR 0.69, 95%-CI 0.61-0.79, $P<0.001$) whereas GLP1-RA did not have a significant effect (HR 0.93, 95%-CI 0.83 to 1.04, $p=0.20$). Both GLP1-RA (HR 0.82, 95%-CI 0.75-0.89, $p<0.001$) and SGLT2i (HR 0.62, 95%-CI 0.58-0.67, $p<0.001$) reduced the risk of progression of kidney disease including macroalbuminuria, but only SGLT2i reduced the risk of worsening eGFR, end-stage kidney disease, or renal death (HR 0.55, 95%-CI 0.48-0.64, $p<0.001$).

Conclusions: In trials reported to date, GLP1-RA and SGLT2i reduce atherosclerotic MACE to a similar degree in patients with established ASCVD, whereas SGLT2i have a more marked effect on preventing HHF and progression of kidney disease. Their distinct clinical benefit profiles should be considered in the decision-making process when treating patients with T2DM.

Key Words: Sodium-glucose cotransporter-2 inhibitors; Glucagon-like peptide 1 receptor agonists; Type 2 diabetes; Meta-analysis

Clinical Perspective

What is new?

- SGLT2i and GLP1-RA reduce atherosclerotic MACE to a similar degree in patients with established atherosclerotic cardiovascular, but have no appreciable effect on MACE over the timeframe studied in patients without established disease.
- SGLT2i but not GLP1-RA reduce the risk of heart failure.
- In terms of renal outcomes, GLP1-RA primarily reduce the risk of macroalbuminuria whereas SGLT2i reduce the risk of worsening eGFR.

What are the clinical implications?

- GLP1-RA and SGLT2i reduce atherosclerotic MACE in patients with established ASCVD, whereas SGLT2i also have effects on preventing HHF and reduction in eGFR in a broad spectrum of patients.
- These considerations should be included in the decision-making process when treating patients with T2DM.



Circulation

Introduction

Recent large-scale cardiovascular outcomes trials that have been mandated by regulatory authorities^{1,2} to prove cardiovascular safety for the approval of new antihyperglycemic agents in patients with type 2 diabetes (T2DM) have contributed to a better understanding of the disease over the last decade. Their large sample sizes and robust results have dramatically changed the landscape of clinical trials in the field of diabetes and caused a shift in therapeutic focus from reducing glycated hemoglobin (HbA1c) in order to prevent microvascular complications to also reducing risk of cardiovascular outcomes. To date, only members of two drug classes, glucagon-like peptide 1 receptor agonists (GLP1-RA)³⁻⁵ and sodium-glucose co-transporter-2 inhibitors (SGLT2i),^{6,7} have been shown to reduce significantly the risk of major cardiovascular events (MACE), the composite of myocardial infarction, stroke, and cardiovascular death. For that reason, recent guidelines focus on initiation of these 2 classes of medications.^{8,9} A recent meta-analysis from our group showed that the favorable effects of SGLT2i on reducing atherosclerotic cardiovascular events are confined to patients with established ASCVD, but their salutary effects preventing hospitalization for heart failure (HHF) and the progression of kidney disease were seen in all patients.¹⁰ A recent meta-analysis of GLP1-RA cardiovascular outcomes trials, which did not include the HARMONY Outcomes trial, showed a 10% reduction in MACE¹¹ but differences in the treatment effect of GLP1-RA on MACE between patients with and without ASCVD have not been confirmed, as primary prevention patients represent only a relatively small proportion of the patient population in each of the trials yielding much fewer events thereby resulting in underpowered analyses. As such, the present meta-analysis of cardiovascular outcomes trials was designed to compare and contrast the clinical benefit of GLP1-RA and SGLT2i in patients with and without established ASCVD.

Methods

The authors declare that all supporting data are available within the article [and its online supplementary files].

Data Search and Study Selection:

The present meta-analysis was performed using the methods proposed in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA-P) statement.¹²⁻¹⁴ A data search of all randomized, placebo-controlled, cardiovascular outcomes trials of GLP1-RA and SGLT2i was performed using PubMed and EMBASE until November 11, 2018 and complemented by results presented at the congress of the American Heart Association 2018. The search algorithm is presented in detail in the Supplemental material. Data search and extraction was performed by two independent reviewers (TAZ, RHMF) using a standardized data form and any discrepancies were resolved by consensus or by consulting a third reviewer (MSS). No patients were involved in the conduction of this meta-analysis and thus no informed consent and institutional review board approval was required. All trials met criteria for being well conducted and had low risk of bias using the Cochrane tool for assessing risk of bias in randomized clinical trials¹⁵ (see Supplemental Table 1).

Patient Subtypes & Outcomes

Patients were stratified into those with established ASCVD versus patients with multiple risk factors (MRF) for ASCVD (see Supplementary Table 2 for details). Efficacy outcomes of interest included MACE (and its individual components), HHF, and progression of kidney disease. The latter included both a broad composite consisting of new onset of macroalbuminuria, worsening of estimated glomerular filtration rate (eGFR), end-stage kidney disease, or death due to renal causes and a narrower kidney outcome excluding

macroalbuminuria. For this latter outcome, sustained doubling of serum creatinine was available for the GLP1-RA trials (except for EXSCEL for which 40% worsening GFR, end-stage kidney disease, or death due to renal causes was available),^{4, 5, 16-18} whereas a composite of doubling of serum creatinine or a $\geq 40\%$ worsening GFR, end-stage kidney disease, or death due to renal causes was available for the SGLT2i trials,¹⁹⁻²¹ but the latter two elements constituted only 0.002% of the events (see Supplementary Table 3 for details).

Statistical analysis

Hazard ratios with 95% confidence intervals for the effect of randomized treatment allocation on the aforementioned outcomes were pooled across trials overall by drug class and within patients with ASCVD and MRF. Whenever data are summarized within a single drug class, fixed effects models were considered to estimate the overall treatment effect under the hypothesis that there is one common treatment effect within the same drug class. When testing for treatment effect modification by drug class, random effects models were considered with drug class as the moderator to make an inference by applying the method of residual maximum likelihood (REML) and Hartung-Knapp adjustment.²² When combining the two drug classes and patient types to examine the treatment difference between patients with ASCVD and MRF, a mixed-effects model was considered to account for heterogeneity of the drug class level and at the trial level with an ASCVD and MRF patient type as a fixed effects moderator. Additional trial level covariates such as pharmacological subclass (human GLP-1 analogues vs exendin-based therapy) and ACS vs no ACS population (Acute coronary syndrome), duration of study follow-up period and absolute difference in HbA1c level reduction (see Supplemental Methods) were also examined in meta-regression models to understand between trial differences for GLP1-RA class. Heterogeneity was assessed using Cochrane Q statistic, and Higgins' and Thompsons I^2 .

Heterogeneity was considered to be low, moderate, or high if I^2 was 25%, 50%, or 75%, respectively.²³ All reported P values are two-sided and no adjustments for multiple testing were performed. Statistical analyses were performed using R version 3.5.1 (R Core Team, Vienna, Austria) and the R package “metafor” (version 2.0-0).²⁴

Results

Study characteristics

We identified a total of 8 trials, 5 GLP1-RA^{3-5, 25, 26} trials and 3 SGLT2i^{6, 7, 21} trials that were eligible for inclusion (Table 1). Supplemental Figure 1 shows an overview of the search and the selection process. In total, data from 77,242 patients, 42,920 (55.6%) patients in GLP1-RA trials and 34,322 (44.4%) patients in SGLT2i trials, were included. The mean age of patients (range 60-65 years) and the proportion of women (range 28-40%) were similar across the trials. A total of 56,473 patients (73.1%) had established ASCVD, but this proportion ranged from 41% to 100% across the trials. A total of 12,568 patients (16.3%) had a history of heart failure, and this proportion ranged from 10 to 24% across the trials. The proportion of patients with eGFR <60 ml/min/1.73 m² ranged from 20% to 29% across the trials, with the exception of DECLARE-TIMI 58 that had a substantially smaller proportion (7.4%).

Composite of myocardial infarction, stroke, and cardiovascular death (MACE)

In total, 8,213 of 77,242 patients (10.6%) experienced a MACE event (4,871 patients in the GLP1-RA trials and 3,342 patients in the SGLT2i trials). A total of 84.7% of these events occurred in the group with established ASCVD.

Overall, both drug classes reduced MACE by a similar magnitude, with GLP1-RA reducing the relative risk by 12% (HR 0.88, 95% CI 0.84 to 0.94; $p < 0.001$; Supplemental Figure

2) and SGLT2i by 11% (HR 0.89, 95% CI 0.83 to 0.96; $p=0.001$; p for heterogeneity 0.86). For both drug classes, this effect was restricted to a 14% reduction in those with established ASCVD (HR 0.86, 95% CI 0.80 to 0.93), with nearly identical effects for GLP1-RA (HR 0.87, 95% CI 0.82-0.92) and SGLT2i (HR 0.86, 95% CI 0.80-0.93), whereas no treatment effect was seen in patients with MRF (HR 1.01, 95% CI 0.87 to 1.19) (Figure 1, P -interaction=0.028; Supplemental Figure 3). The observed heterogeneity between GLP1-RA (p -interaction 0.06) and SGLT2i (p -interaction 0.05)¹⁰ was similarly in both drug classes. There was borderline evidence of heterogeneity among the GLP1-RA trials ($Q=9.72$, $p=0.046$; $I^2=58.8\%$) for the effect estimate on MACE. Stratifying the drug class by pharmacological subclass showed a non-significant trend towards greater benefit for the human GLP-1 analogues (HR 0.82, 95% CI 0.76 to 0.89, $P<0.001$) than for the exendin-based therapies (HR 0.94, 95% CI 0.87 to 1.02, $P=0.14$) but the difference was not statistically significant (p -interaction 0.12). However, one of the trials using the exendin-based GLP1-RA lixisenatide was in the post-acute coronary syndrome (ACS) setting, in which MACE risk may be less acutely modifiable by a metabolic agent. Examining all of the non-ACS trials, the overall HR was 0.86 (95% CI 0.81 to 0.91, $P<0.001$) with no significant heterogeneity ($Q=4.75$, $p=0.19$; $I^2=36.8\%$). Furthermore, the median trial duration (p -interaction 0.69) did not modify significantly the treatment effect of GLP1-RA. There was a trend for greater risk reduction with greater HbA1c lowering (P -interaction overall 0.055, ASCVD subgroup only 0.032) but this was not significant after the removal of the ELIXA trial (p -interaction overall 0.28, ASCVD subgroup only 0.22).

Treatment effect on the individual components of MACE

There were 4,274 patients who experienced a myocardial infarction (2,670 patients in GLP1-RA trials and 1,604 patients in SGLT2i trials), 2,237 a stroke (1,177 patients in GLP1-RA trials,

1,060 patients in SGLT2i trials), and 3,132 a cardiovascular death (1,876 in GLP1-RA trials, 1,256 patients in SGLT2i trials).

Both GLP1-RA and SGLT2i reduced the relative risk of myocardial infarction: by 9% with GLP1-RA (HR 0.91, 95% CI 0.84 to 0.98, $p=0.012$) and by 11% with SGLT2i (HR 0.89, 95% CI 0.80 to 0.98, $p=0.018$; p for heterogeneity 0.87; Supplemental Figure 4). In contrast, GLP1-RA reduced the relative risk of stroke significantly by 14% (HR 0.86, 95% CI 0.77 to 0.97, $p=0.012$), whereas SGLT2i had no effect (HR 0.97, 95% CI 0.86 to 1.10) (p for heterogeneity 0.25; Supplemental Figure 5). Both drug classes significantly reduced the relative risk of cardiovascular death: by 12% with GLP1-RA (HR 0.88, 95% CI 0.80 to 0.96, $p=0.004$) and by 16% with SGLT2i (HR 0.84, 95% CI 0.75 to 0.94, $p=0.002$; p for heterogeneity 0.51; Supplemental Figure 6).

Hospitalization for heart failure

In total, HHF occurred in 2,240 individuals, 1,278 in the GLP1-RA trials (not including data from the HARMONY trial that did not directly report that outcome) and 962 patients in the SGLT2i trials. Overall, GLP1-RA did not statistically significantly reduce the relative risk of HHF (HR 0.93, 95% CI 0.83 to 1.04, $p=0.20$) whereas SGLT2i did reduce the relative risk for HHF by 31% (HR 0.69, 95% CI 0.61-0.79, $p<0.001$) (P for heterogeneity 0.003, Figure 2). These findings, including the significant interaction, remained similar in a sensitivity analysis after including estimated treatment effect data from the HARMONY trial (see Supplementary Results).

Treatment Effects on Kidney Function

Overall, the broad composite kidney endpoint occurred in 5,071 patients. GLP-1RA reduced the relative risk of the broad composite kidney outcome significantly by 18% (HR 0.82, 95% CI 0.75

to 0.89, $p < 0.001$), whereas there was a 38% reduction with SGLT2i (HR 0.62, 95% CI 0.58 to 0.67, $p < 0.001$; P for heterogeneity 0.010; Figure 3A). Moreover, the relative risk reduction of the kidney composite with GLP1-RA appeared to be mainly driven by a reduction in macroalbuminuria. Excluding that particular outcome, there was a non-significant effect of GLP1-RA on the risk of doubling serum creatinine (HR 0.92, 95% CI 0.80 to 1.06, $p = 0.24$). Conversely, SGLT2i significantly reduced the relative risk of worsening eGFR, end-stage kidney disease, or renal death by 45% (HR 0.55, 95% CI 0.48 to 0.64, $p < 0.001$; P for heterogeneity = 0.001; Figure 3B). A sensitivity analysis using doubling of serum creatinine alone yielded an almost identical effect estimate (HR 0.56, 95% CI 0.44-0.71, $P < 0.001$).



Discussion

GLP1-RA and SGLT2i are antihyperglycemic agents that have now been demonstrated to reduce the risk of cardiovascular events in patients with type 2 diabetes mellitus.¹¹ The relative benefits of these drugs in different patient populations remains undefined. The present meta-analysis showed that both GLP1-RA and SGLT2i reduce the risk of MACE by approximately 14% in patients with known ASCVD, whereas in the trials published to date, neither reduces the risk of MACE in patients with only MRF but without established ASCVD.

In terms of the individual components of MACE, both classes reduced the risk of MI and CV death, but only GLP1-RA reduced the risk of stroke. In contrast, SGLT2i robustly reduced the relative risk of HHF by 31%, whereas there was only a non-significant 7% relative risk reduction with GLP1-RA.

Members of GLP1-RA have been found to reduce kidney events mainly driven by a reduction in macroalbuminuria.¹⁶ Although albuminuria is a well-established biomarker

reflecting risk for diabetic kidney disease and cardiovascular disease,^{27, 28} it represents a surrogate marker and may even be absent in patients with reduced eGFR.^{29, 30} As such, reductions in eGFR has emerged as the more meaningful endpoint of greater importance and is used in ongoing diabetes trials for kidney outcomes.³¹ When excluding macroalbuminuria, we found a non-significant relative reduction by 8%. This stands in contrast to a recent meta-analysis of SGLT2i that showed robust relative risk reductions by 45% for the composite of reductions in eGFR, end-stage kidney disease, and death due to renal causes.¹⁰

The exact pathobiological explanations how these two drug classes exert their favorable effects are still unclear.^{10, 32-34} Both drug classes have modest and relatively similar reductions of HbA1c and therefore appear to exert their beneficial cardiovascular effects independent of glucose control through their individual pleiotropic properties. However, the natriuresis and inhibition of the tubuloglomerular feedback by SGLT2i may play a central role and explain the observed reduction in HHF and the delayed progression of diabetic kidney disease.³⁵ Potentially adding to the complexity, structural differences in the GLP1-RA group might explain somewhat more pronounced effects with the human GLP-1 analogues compared with the exendin-based GLP1-RAs. Recently, a press release has been issued stating that the REWIND trial, a cardiovascular outcomes trial comparing the GLP1-RA dulaglutide in approximately 9900 patients (68.6% of whom did not have known ASCVD), has met its primary endpoint of reducing the risk of MACE.^{36 37} Detailed results have not yet been presented or published, including any heterogeneity in benefit between patients with established ASCVD and those only with MRF for ASCVD. However, its uniquely long duration of 8 years raises the possibility that a reduction in MACE may require more time to become evident in patients with lower risk for MACE. It is biologically plausible that SGLT2i and GLP1-RA have the same benefit in both

patient populations, but the treatment effect may require more time to become evident in patients at lower-risk.

Limitations

There are several potential limitations to address. We have included aggregate trial-level data instead of patient-level data, and as such, observed differences in treatment effects between subgroups have been analyzed only based on a single factor of stratification. However, a more complex interplay involving multiple baseline characteristics may exist. In addition, the exact inclusion/exclusion criteria and definitions of endpoints differed slightly among the included trials. As such, a higher risk patient cohort with a larger proportion of patients with ASCVD and lower eGFR baseline levels was included in the GLP1-RA trials. This meta-analysis aimed to provide clinical context and show their clinical efficacy of two drug classes in specific patient populations. However, trials with head to head comparison would be necessary to demonstrate possible superiority of one drug class over the other. Also, this meta-analysis is not able to evaluate potential incremental or additive treatment effects when both drug classes are combined. Further research is warranted to explore the cardiovascular and kidney effects of combining the two treatment regimens. As noted above, the REWIND data were not included, as this trial has not been published at the time of submission. However, based on topline results of superiority reported by press release, they raise the possibility that very long-term treatment with a GLP1RA may reduce the risk of MACE in patients without established ASCVD.³⁷

Conclusion

In conclusion, GLP1-RA and SGLT-2i reduce the risk of MACE to a similar degree in patients with established ASCVD, but have no effect in patients without established ASCVD over a short-term follow-up ranging from 2 to 4 years. The prevention of heart failure and progression

of kidney disease by SGLT2i should be considered in the decision-making process when treating patients with T2DM.

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Table 1. Summary of GLP1-RA and SGLT2i cardiovascular outcomes trials

	GLP-1RA					SGLT2i		
Trial	ELIXA	LEADER	SUSTAIN-6	EXSCEL	HARMONY	EMPA-REG OUTCOME	CANVAS Program	DECLARE-TIMI 58
Drug	Lixisenatide	Liraglutide	Semaglutide	Exenatide	Albiglutide	Empagliflozin	Canagliflozin	Dapagliflozin
Median Follow-Up Time (years)	2.1	3.8	2.1	3.2	1.6	3.1	2.4	4.2
Trial participants (n)	6068	9340	3297	14752	9463	7020	10142	17160
Age (mean)	60.3	64.3	64.6	62.0	64.1	63.1	63.3	63.9
Female Sex	2894 (30.7%)	3337 (35.7%)	1295 (39.3%)	5603 (38.0%)	2894 (30.6%)	2004 (28.5%)	3633 (35.8%)	6422 (37.4%)
Proportion of Patients with Established Atherosclerotic Cardiovascular Disease (n, %)	6068 (100%)	6775 (72.5%)	2735 (83.0%)	10782 (73.1%)	9463 (100%)	7020 (100%)	6656 (66%)	6974 (41%)
History of Heart Failure (n, %)	1922 (20.3%)	1667 (17.8%)	777 (23.6%)	2389 (16.2%)	1922 (20.3%)	706 (10.1%)	1461 (14.4%)	1724 (10.0%)
eGFR <60 ml/min/1.73m ² (n, %)	1407 (23.2%)	2158 (23.1%)	939 (28.5%)	3191 (21.6%)	NA	1819 (25.9%)	2039 (20.1%)	1265 (7.4%)

The CANVAS Program consisted of 2 trials, the CANVAS and CANVAS-R trials, but are presented combined.

Figure Legends

Figure 1. Meta-Analysis of GLP1-RA and SGLT2i trials on the composite of myocardial infarction, stroke, and CV death (MACE) stratified by presence of atherosclerotic cardiovascular disease

Forest plot showing the treatment estimates of each drug class in each subgroup using fixed effects. The summary estimates for each subgroup were modeled using random effects accounting for heterogeneity of the different drug classes. The test for subgroup differences was based on a F-test in a random effect meta-regression using mixed effects accounting heterogeneity for drug class and patient population.



P-value for subgroup differences: 0.028

Established ASCVD:

GLP-1RA: Q-statistic= 10.89, p=0.028; I^2 =63.3%

SGLT2i: Q-statistic= 0.94, p=0.63; I^2 = 0%

Total: Q-statistic= 11.85, p=0.11

MRF:

GLP-1RA: Q statistic=0.24, p=0.89; I^2 =0%

SGLT2i: Q-statistic= 0.033, p=0.86; I^2 =0%

Total: Q-statistic=0.34, p=0.99

Figure 2. Meta-Analysis of GLP1-RA and SGLT2i trials on hospitalization for heart failure stratified by drug class

Forest plot showing the treatment estimates of each drug class using fixed effects. The test for subgroup differences between the 2 drug classes was based on a F-test in a random effect meta-regression using mixed effects accounting heterogeneity for drug class.

P-value for subgroup differences 0.003

GLP1-RA: Q-statistic= 1.48, p=0.69; $I^2=0\%$

SGLT2i: Q statistic=0.60, p=0.74; $I^2=0\%$

Figure 3. Meta-Analysis of GLP1-RA and SGLT2i trials on renal endpoints.



A. Meta-Analysis of GLP1-RA and SGLT2i trials on hospitalization for a broad kidney

endpoint (new-onset macroalbuminuria sustained doubling of serum creatinine or a 40% decline in eGFR, ESRD, or death of renal cause) stratified by drug class

Forest plot showing the treatment estimates of each drug class using fixed effects. The test for subgroup differences between the 2 drug classes was based on a F-test in a random effect meta-regression using mixed effects accounting heterogeneity for drug class.

P-value for subgroup differences 0.010

GLP1-RA: Q-statistic= 3.60, p=0.31; $I^2=16.6\%$

SGLT2i: Q statistic=3.48, p=0.18; $I^2=42.5\%$

B. Meta-Analysis of GLP1-RA and SGLT2i trials on a kidney outcome excluding macroalbuminuria stratified by drug class

Forest plot showing the treatment estimates of each drug class using fixed effects. The test for

subgroup differences between the 2 drug classes was based on a F-test in a random effect meta-regression using mixed effects accounting heterogeneity for drug class.

P-value for subgroup differences <0.001

GLP1-RA: Q-statistic= 2.18, p=0.54; I^2 =0%

SGLT2i: Q statistic= 0.59, p=0.74; I^2 =0%



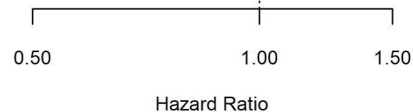
Circulation

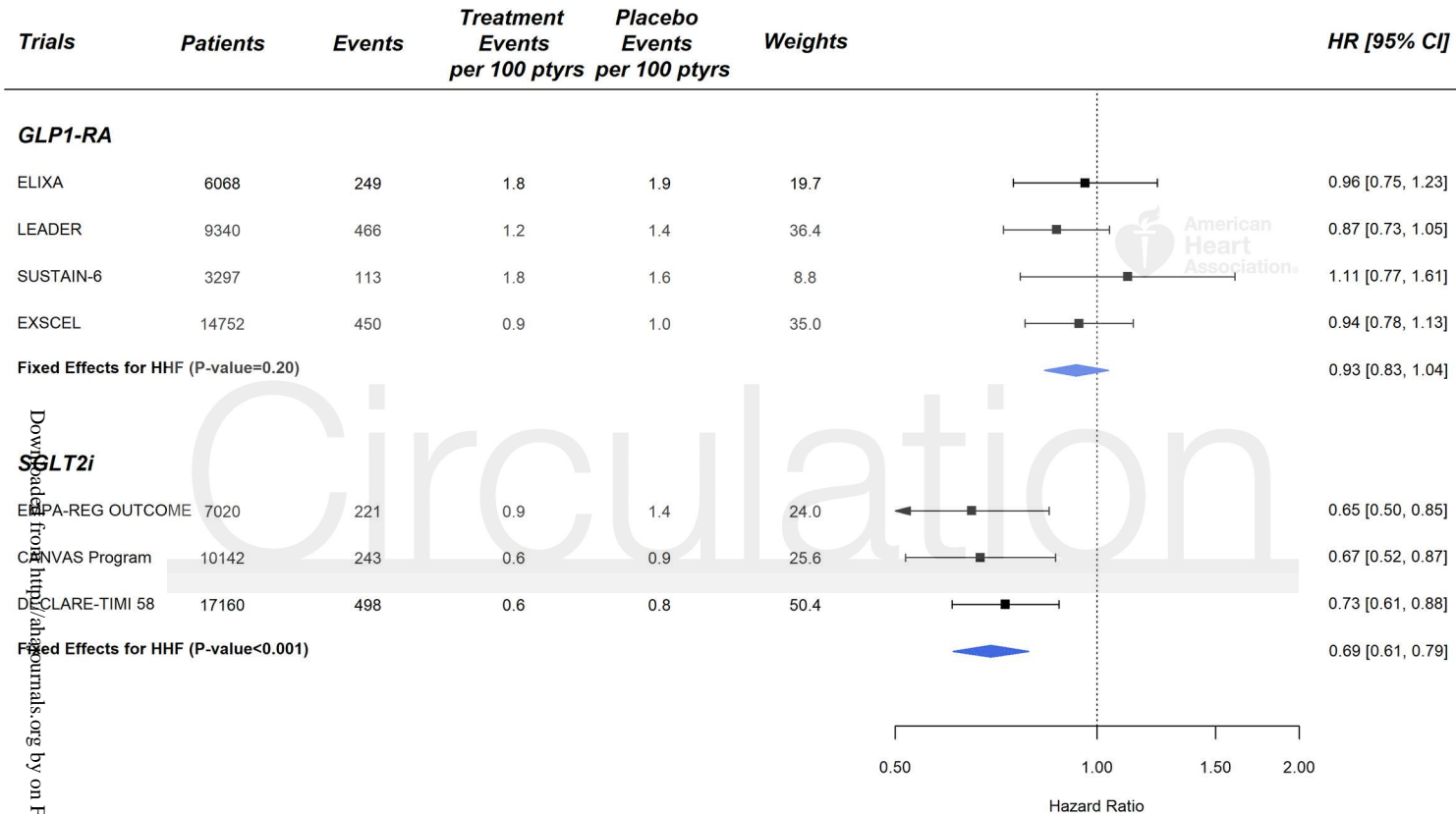
<i>Trials</i>	<i>Patients</i>	<i>Events</i>	<i>Weights</i>		<i>HR [95% CI]</i>
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Established Atherosclerotic Cardiovascular Disease

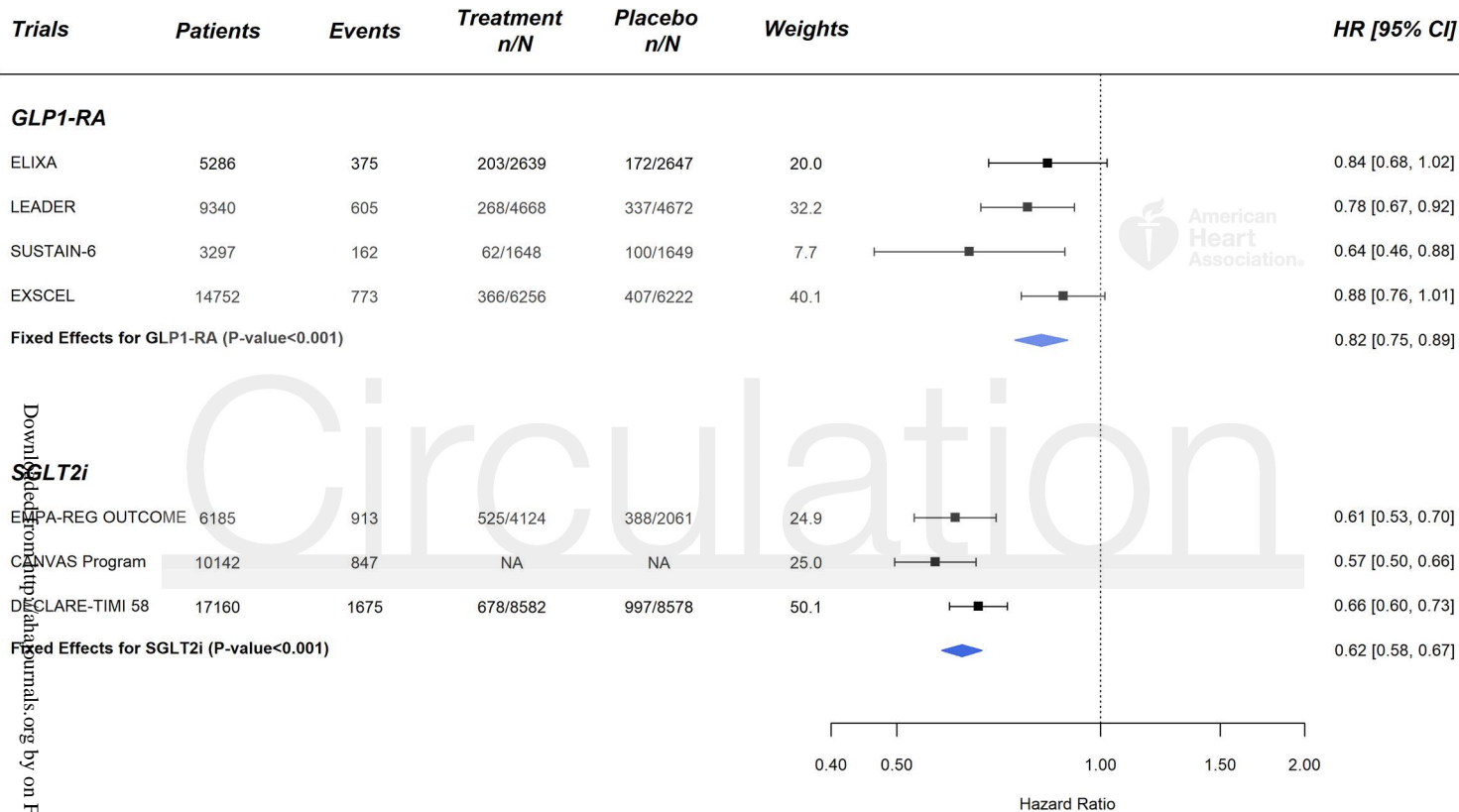


Multiple Risk Factor





A.)



B.)

