Prevalence of acute kidney injury after cardiac surgery:A systematic review and meta-analysis on risk factors and different diagnostic criterias(AKIN,RIFLE,KDIGO)

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Research article

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Abstract

Objective: This systematic review and meta-analysis aimed to determine the incidence and some of risk factors of AKI after cardiac surgery using all three diagnostic criteria (AKIN,RIFLE, and KIDGO).

Method: We searched for published literature in the English language in MEDLINE via PubMed, EMBASETM via Ovid, The Cochrane Library, and Trip database. For literature published in other languages, we searched national databases (Magiran and SID) , KoreaMed and LILACS, and we searched OpenGrey (www.opengrey.eu/) and the World Health Organization Clinical Trials Registry (who.int/ictrp) for unpublished literature and ongoing studies.To ensure the literature saturation, the list of the included research references or the relevant reviews found by searching was studied(MS). The keywords used in the search strategy were Acute kidney injury,acute renal failure, creatinine,cardiac surgery,heart surgury, *Coronary artery bypass grafting*(CABG),valve replacement,RIFLE (risk, injury, failure, loss, end-stage renal disease) ,Acute Kidney Injury Network (AKIN),KDIGO (Kidney Disease: Improving Global Outcomes) , which were combined using the AND, OR, and NOT operators.

Results: A total of 33298 patients who had undergone the cardiac surgery were studied. Based on the random effect model the total prevalence of AKI in 33298 patients undergone the heart surgery was 26.3% (95% confidence interval[CI]:26.1%,26.6%, I^2=99.5%). the total prevalence of AKI in patients undergone cardiac surgery based on AKIN criteria was 21.6% (95% CI –21.2%, 22.1%,I^2=98.5%) of whom 21.6% (95% CI-21.2%,22.1%,I^2=98.5%) were classified as AKIN stage 1, whereas 3% (95% CI-2.7%%,3.4%%,I^2=90.6%) were classified as AKIN stage 2, and 3.2% (95% CI-3.0%%,3.4%%,I^2=97.2%) were classified as AKIN stage 3. the total prevalence of AKI in patients undergone cardiac surgery based on RIFLE criteria was 26.0%% (95% CI –25.6%, 26.5%,I^2=99.4%). total prevalence of AKI in patients undergone cardiac surgery based on KDIGO criteria was 34.7% (95% CI –33.8%, 35.7%,I^2=98.4%). the highest prevalence of AKI in patients undergone cardiac surgery was in Brazil 45.7% (95% CI –43.6%, 47.8%) based on 3 articles included followed by USA with a prevalence of 29.6%(95% CI –28.7%, 29.4%) based on 7 articles included, Uruguay with a prevalence of 36.1%(95% CI –35%, 37.2%) based on 1 article, Canada with a prevalence of 16.7% (95% CI –15.7%, 17.6%) based on 4 articles included and Italy with a prevalence of 10.6%(95% CI –9.8%, 11.3%) based on 3 articles included.

Conclusion: AKI after cardiac surgery is a common symptom, although most often more severe in elderly patients. The prevalence of AKI after cardiac surgery based on KDIGO criteria was found to be higher than RIFLE and AKIN. The prevalence of AKI regardless of the definition used showed a decreasing trend from 2009 to 2019. Our findings pointed to the superiority of the KDIGO criterion over RIFLE and AKIN for diagnosing and evaluating AKI after cardiac surgery. However, the widespread acceptance of consensus definitions (RIFLE and AKIN criteria) for AKI is still reflected in the studies. In order to progress further, establishment of a uniform definition for AKI seems necessary.

Background

Acute renal injury (AKI) as a severe complication occurs in 3.5–31.0% of the patients who undergo cardiac surgery, and was found to be one of the most common complications affecting these patients (1). Acute kidney injury (AKI) after cardiac surgery increases the mortality rate (2–5), prevalence of complications, ICU and hospital stay, and health care costs(6–8)In a study conducted by Kochi et al.(9), the postoperative AKI prevalence in patients undergone the heart surgery was 34.0%. In contrast, some studies including Santos et al.(10), Chertow et al.(11)and Conlon et al.(12),reported prevalence rates of 16.1%, 2.4%, and 1.1%, respectively. The considerable inconsistency in the post-cardiac surgery AKI prevalence can be mainly attributed to the variation of the diagnostic criteria used (13).To develop a standardized definition of acute renal failure, the Acute Dialysis Quality Initiative Workgroup released the RIFLE classification which covers the three stages of acute renal dysfunction,:risk (R), injury (I), and failure (F) based on baseline changes in sCr, the estimated glomerular filtration rate, and urine output, as well as the two clinical outcomes of loss (L) and end-stage kidney disease (E), based on the length of required renal replacement therapy (14). In light of the fact that little changes in sCr compared to the changes proposed by the RIFLE definition can also be associated with adverse outcomes, AKIN definition and classification were proposed by the Acute Kidney Injury Network (AKIN, 2006). These criteria cover the three stages corresponding to the RIFLE risk, injury, and failure stages, respectively (15). The main difference between the two classifications lies in the fact that the AKIN criteria requires a period of 48 hours for detecting changes in renal function and a smaller change in sCr than RIFLE criteria, aiming to improve the sensitivity and early detection of AKI. Moreover, the AKIN criteria do not entail the knowledge of a baseline sCr. In contrast, they regard the kidney injury as any acute increase in sCr establishing the criteria. Some risk factors affecting acute kidney injury are older age, male gender, diabetes mellitus (16), and the pre-existing chronic kidney disease as the most important one (17).. It also serves as a predictor of acute kidney injury found in the postoperative time (18). Despite several attempts indetermining the etiology and prophylactic measures, there is limited data on its incidence and predictors in the post-cardiac operative stage based on all three different definitions and diagnostic criteria. This systematic review and meta-analysis aimed to determine the incidence and some of risk factors of AKI after cardiac surgery using all three diagnostic criteria (AKIN,RIFLE, and KIDGO).

Methods

Inclusion Criteria

The methods used in this systematic review were developed based on the PRISMA guidelines. Cross-sectional studies, case-control, and cohort studies were included in this study, while case studies, letters to editors, case reports, clinical trials, study protocols, systematic reviews, and review articles were excluded.

Participants: All studies on the prevalence of acute renal failure in patients undergoing cardiac surgery were reviewed.

Results: The main purpose of this study was to determine the prevalence of acute renal failure in patients undergoing cardiac surgery and the data were collected according to the released reports.

Sampling Methods and Sample Size: All observational studies were included in the systematic review regardless of their design. The minimum sample size was 25 patients.

Searching Strategy

The searches were conducted by two independent researchers to find studies published from 1/1/2009 to 30/5/2019. Studies published in MEDLINE were searched through PubMed, EMBASETM via Ovid, the Cochrane Library, and the TRIP database. For studies published in other languages, national databases (Magiran and SID, KoreaMed, and LILACS) were searched. Besides, unpublished studies and ongoing studies were searched in OpenGrey (www.opengrey.eu/) and the WHO International Clinical Trials Registry Platform (who.int/ictrp). To ensure that the studies were adequate, the list of research resources or relevant reviews found through searching, and systematic review articles were checked using MeSH and open-ended terms following publication standards. After the MEDLINE strategy was finalized, the results were compared to search for other databases. PROSPERO was also searched to find recent or ongoing reviews .the keywords used in the search strategy were: Acute kidney injury, acute renal failure, creatinine, cardiac surgery, coronary artery bypass grafting (CABG), valve replacement, RIFLE (risk, injury, failure, loss, end-stage renal disease), Acute Kidney Injury Network (AKIN), KDIGO (Kidney Disease: Improving Global Outcomes) which were combined using the AND, OR, and NOT operators.

Study Selection and Data Extraction

Two researchers independently reviewed the research titles and abstracts based on the inclusion criteria. After excluding repeated studies, the full manuscripts of the studies were reviewed according to the inclusion criteria and the data and information about the authors were collected if necessary. The data extracted included general information (the author(s), province, and year of publication), study information (sampling technique, diagnostic criteria, the method of data collection, research conditions, the sample size, and risk of bias) and output scale (prevalence of acute kidney injury).

Quality Assessment

To assess the quality of the methodology and the bias risk, each observational study was evaluated using the scale developed by Hoy et al. This 10-item scale assessed the quality of the study in terms of the external validity (items 1 to 4 used to assess the target population, the sampling frame, the sampling method, and the minimum participation bias) and the internal validity (items 5 to 9 used to assess the methods of data collection, the problem statement, and the instruments and scale, and item 10 evaluates the analysis bias). The risk of bias was assessed independently by the two researchers and any inconsistency in the obtained values was resolved by consensus.

Data Collection Procedure

All studies that met the inclusion criteria were used in the data collection process after systematic review and data were mixed using the funnel plot. The random-effects model was evaluated based on the overall prevalence of the disease among the participants. The heterogeneity of the initial studies was assessed using the I^2 test. Besides, the subgroups were analyzed to determine heterogeneity by the participants' age, year of publication, and country. Finally, a meta-analysis of the collected data was performed using STATA14 software.

Results

Research Selection

A total of 1413 articles were extracted through preliminary searches in various databases. Of the 1294 studies identified by the analysis of titles and abstracts, 387 were eliminated because of irrelevant titles. Out of 907 existing articles, 657 articles were excluded for some reasons. Of the 657 excluded studies, 377 did not have a complete manuscript, 25 were review articles, 7 were letters to the editor-in-chief, and 248 did not meet the inclusion criteria. Of the remaining 250 studies, 22 met the inclusion criteria (Fig.1).

Research characteristics

A total of 33,298 patients who underwent heart surgery were evaluated. Of the 21 studies, 9 were retrospective, 11 were prospective, and the research design was not mentioned in the other study. A total of 21 studies from 6 countries that met the inclusion criteria were reviewed. Among these studies, 7 studies were from United States (25,34,36-38,41,42), 4 studies from Canada (25,32,35,40), 3 studies from Brazil (22,24,27) 3 studies from Italy (28,31,39), one study from England (30), one from Uruguay (23), and one was study from New England (29). Convenient sampling was used to select the participants (n = 21). The risk of bias was low in most studies. The data were collected mainly from the patients' medical records and especially from the intensive care units (n = 20). Of the 21 selected studies, 8 studies met the Acute Kidney Injury Network (AKIN) criteria (22,25-27,34,37,39,41), 6 studies were in line with RIFLE criteria (31,32, 33,36,40,42). And 2 studies met the Kidney Disease Improving Global Outcomes (KDIGO) criteria to diagnose acute renal failure (23, 24). Besides, 3 studies used both AKIN and RIFLE criteria (37, 28, 28) and one study used both AKIN and KDIGO criteria (30) (Table 1).

The meta-analysis of the frequency of acute renal failure after cardiac surgery

According to the random-effects model, the prevalence of acute renal failure in 33298 patients with cardiac surgery was 26.3% (CI[1] = 95%, I^2 = 99.5%, 26.1-26.6%) (Fig. 2, Table 2).

Subgroup analysis

The meta-analysis of the prevalence of acute renal failure after cardiac surgery based on the AKIN criteria

According to the random effects model and the AKIN criteria, the overall prevalence of acute renal failure in patients undergoing cardiac surgery was 21.6% (21.2% - 22.1%, CI = 95%, I = 98.5%). Among this population, 21.6% was classified as the AKIN first stage, 3% (2.7% -3.4% as CI = 95%, I^2 = 90.6%) as the AKIN second stage and 3.2% were classified as the AKIN third stage (3% -3.4%, CI = 95%, I^2 = 97.2%) (Table 3, Fig. 3).

The meta-analysis of the prevalence of acute renal failure after cardiac surgery according to the RIFLE criteria

According to the random-effects model and the RIFLE criteria, the overall prevalence of acute renal failure in patients undergoing cardiac surgery was 26.0% (25.6% - 26.5%, CI = 95%, I^2 = 99.4%) (Table 4, Fig. 4).

The meta-analysis of the prevalence of acute renal failure after cardiac surgery according to KDIGO criteria

According to the random-effects model and KDIGO criteria, the overall prevalence of acute renal failure in patients undergoing cardiac surgery was 34.7% (33.8%-35.7%, CI = 95%, I^2 = 98.%) (Table 5, Fig. 5).

Meta-analysis of the prevalence of acute renal failure after heart surgery by country:

Based on the random-effects model, the highest prevalence of acute renal failure in patients undergoing cardiac surgery in Brazil was 45.7% (47.6% 43.6-47.8%, CI = 95%) [22, 24, 27]. The prevalence rate in the United States was 29.6% (29.4% -28.7%, CI = 95%) [25, 34, 36-38, 41, 42] and the prevalence rate in Uruguay was 36.1% (35-37.2%, CI = 95%) [23]. The corresponding value for Canada was 16.7% (15.7-17.6%, CI = 95%) [25, 32, 35, 40]. Finally, the prevalence of acute renal failure in Italy was 10.6% (9.8-11.3%, CI = 95%) [28, 31, 39] (Fig. 7).

A meta-analysis of the prevalence of acute renal failure after cardiac surgery in children

According to the random-effects model, the overall prevalence of acute renal failure after heart surgery in children was 37.5% (40.9% -34.5%, CI = 95%, I^2 = 94%) (Table 6, Fig. 6).

Meta-Regression Results

Meta-regression between the year of publication and the prevalence of acute renal failure after cardiac surgery

The meta-regression of the studies was evaluated according to the relationship between the prevalence of acute renal failure, the year of publication of the study, and the overall rate of acute renal failure. There were no significant linear trends in the univariate meta-regression to explain the change in the effect size of the year the study was published (Fig. 10).

The results of meta-regression between participants' age and frequency of acute renal failure in patients undergoing cardiac surgery

The regression test was performed to explore the relationship between the prevalence of acute renal failure, the participants’ age, and the total rate of acute renal failure. There was no significant linear trend in univariate meta-regression to explain the effect size of participants' age (Fig. 9).

Publication bias

The funnel plot displayed in Fig. 8 does not show the publication bias and the funnel plot is symmetric. The circle size indicates the size of the studies (larger circles indicate a greater number of samples and smaller circles indicate fewer samples) (Fig. 8).

[1] Confidence interval

Discussion

Nearly, 1 million persons are annually admitted for coronary artery bypass grafting in the world (43). 30% of them are being at the risk of developing AKI (44).Despite all advances made in the AKI pathogenesis and treatment, it is still found as a relatively common complication and an independent risk factor associated with mortality in critically ill patients (45–47). Furthermore, there are still some disagreements about AKI and, in particular, its definition (48). The inconsistency in data on the actual incidence of this complication is the result of the lack of consensus supported by a considerable variation (1% - 30%) in the reported incidence of post cardiac-surgery AKI (44). For instance, Englberger et al. compared the AKIN and RIFLE criteria and found that a significantly greater number of patients were diagnosed as AKI by AKIN (26.3%) compared to RIFLE criteria (18.9%) (P < 0.0001) (49). However, Sampaio et al. reported a prevalence rate of 50.7% by AKIN, 14.9% by RIFLE, and 19.3 % by KDIGO for AKI after cardiac surgery (68).A couple of cohort studies have compared the prognostic implications of the criteria set in AKIN and RIFLE definitions in other clinical settings. A study conducted by Joannidis et al. on ICU patients indicated that RIFLE is a stronger predictor of 30-day mortality compared to AKIN (50). However, Bagshaw et al. (51) who studied a multicenter cohort with 57 intensive care units showed no prognostic difference between RIFLE and AKIN. Similarly, Roy et al. (52) found that KDIGO, RIFLE, and AKIN were not different in predicting 30-day mortality rate in a group of patients suffering from acute decompensated heart failure.

Non-modifiable factors including age, cardiac failure, vascular events, and diabetes are related to mortality over time. Similar results have been also reported in the literature concerning other independent predictors of late mortality including COPD (53,56), baseline renal function (54,55), time on vasoactive drugs(55), hospital stay duration (53), operation period (54), procedural urgency (55,56) and preoperative atrial fibrillation (56).Of the clinical factors under analysis, age was found to be associated with AKI risk irrespective of the criterionused,which probably points to the lower tolerance of older patients to hemodynamic and electrolyte fluctuations typically associated with such a surgical intervention(57,58). A progressive increase in the AKI development among older patients has been found in a number of studies(59–62).As a case in point, Santos et al (62,63). found the age of over 63 is a single risk factor for AKI. Besides, loss of the renal functional reserve due to the gradual decrease in the glomerular filtration rate deteriorated at older ages exposes old patients at the higher risk of renal damage when undergoing hypoperfusion (64,65). The results of the multivariate analysis performed by Romas et al. indicated advanced age, valve replacement surgery, vasoactive drug intake in the postoperative period, and having the history of cardiac surgery as some factors associated with AKI development (65)Another study comparing the same criteria found that identical AKI incidence and outcome rates based on AKIN and KDIGO criteria (66).Bastin et al. found that regardless of the classification used, there is a clear correlation between the severity of AKI after cardiac surgery and risk of mortality (67).The results of another study by Sampaio et al. indicated that that in spite of the association of the three evaluated criteria with an increased risk of adverse outcomes, and even after adjustment for comorbidities and type of surgery, only the KDIGO criterion maintained its predictive power when taking hemodynamic factors (e.g. the time of extracorporeal circulation and low cardiac output) were into account; pointing to the superiority of the KDIGO criterion compared to RIFLE and AKIN (68).

Limitations

The required data were collected from the existing information from various studies. Some studies were clinical trials while others were observational investigations. The plans and objectives of the studies, the input and output indexes and variables, and the data collected were significantly different in these studies. In addition, there were a few studies on the KDIGO criteria as the diagnostic inputs.

Strength

This study is the first systematic review and meta-analysis that compared the prevalence of AKI after cardiac surgery based on three diagnostic criterias. It also compared simple diagnostic instruments based on easily accessible information, even for non-nephrologists; and thus, the present study, despite the limitations described, makes an important contribution to the medical community. This study is also significant for its comprehensive review of all relevant studies, accurate assessment of the bias risk of selected studies using the QUADAS–2 tool, extraction of duplicate data and subgroup analysis, and its sensitivity to investigate differences in the prevalence of AKI in studies with high, low, and no risk of bias

Conclusion

AKI after cardiac surgery is a common symptom, although most often more severe in elderly patients. The prevalence of AKI after cardiac surgery based on KDIGO criteria was found to be higher than RIFLE and AKIN. The prevalence of AKI regardless of the definition used showed a decreasing trend from 2009 to 2019. Our findings pointed to the superiority of the KDIGO criterion over RIFLE and AKIN for diagnosing and evaluating AKI after cardiac surgery. However, the widespread acceptance of consensus definitions (RIFLE and AKIN criteria) for AKI is still reflected in the studies. In order to progress further, establishment of a uniform definition for AKI seems necessary.

List Of Abbreviations

Acute kidney injury: AKI, RIFLE: risk, injury, failure, loss, end-stage renal disease,Acute Kidney Injury Network: AKIN,KDIGO: Kidney Disease: Improving Global Outcomes, Coronary artery bypass grafting: CABG

Declarations

Ethics Approval and Consent to Participate: not applicable.

Consent for publication: not applicable

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*Authors' Contributions:*AA participated in Conception and design of the study, library searches and assembling relevant literature, critical review of the paper, supervising writing of the paper, Database management.MS participated in Data collection, library searches and assembling relevant literature, writing the paper,and critical review of the paper.FP participated in Data collection, library searches and assembling relevant literature, writing the paper, analysis of the data and critical review of the paper. All authors read and approved the final manuscript.

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Tables

Table 1.study characteristics

Author	year	Country	Study design	Study population	Setting	Diagnostic criteria	Mode of data collection	Participants	Ag ± ran
Romas[22]	2018	Brazil	Retrospective	Adult	ICU	AKIN		142	58 13
Ferreiro[23]	2017	Uruguay	Retrospective	Adult	ICU	KDIGO		7075	N/
Machado[24]	2014	Brazil	Retrospective	Adult	ICU	KDIGO		1175	N/
Shlipal[25]	2011	USA	Prospective	Adult	ICU	AKIN		1147	71
Koyner[26]	2013	Canada	Prospective	Adult	ICU	AKIN		1502	N/
Machado[27]	2009	Brazil	prospective	Adult	ICU	AKIN		817	61
Hassc[28]	2009	Italy	Prospective	Adult	ICU	AKIN/RIFLE		282	N/
Robrt[29]	2010	New England	Prospective	Adult	ICU	AKIN/ RIFLE		2508	66
Bastin[30]	2013	UK	Retrospective	Adult	ICU	AKIN/ KDIGO		1881	56
Mariscalco[31]	2014	Italy	Prospective	Adult	ICU	RIFLE		2504	68
Karkouti[32]	2009	Canada	Prospective	Adult	ICU	RIFLE		3460	N/
Hasse-fielits[33]	2009	N/A	N/A	Adult	Terirary] Hospital	RIFLE		100	77
K-Han[34]	2009	USA	Prospective	Adult	ICU	AKIN		90	63
Parikh[35]	2010	Canada	Prospective	Adult	ICU	N/A		1219	71
Meersch[36]	2014	USA	Prospective	Adult	ICU	RIFLE		50	71
MCIlory[37]	2010	USA	Prospective	Adult	ICU	AKIN		426	N/
Englberger[38]	2011	USA	Retrospective	Adult	ICU	AKIN/ RIFLE		4836	67
Parolari[39]	2012	Italy	Retrospective	Adult	ICU	AKIN		3219	N/
Zappitelli[40]	2009	Canada	Retrospective	children	ICU	RIFLE		390	4.7
Blinder[41]	2012	USA	Retrospective	children	ICU	AKIN		255	5-1
Krawczeski[42]	2011	USA	Retrospective	children	ICU	RIFLE		220	0.5

Table 2.meta-analysis of the overall prevalence of AKI in patients undergoing cardiac surgery

First author	Publication year	Country	Prevalence of AKI			
			ES	95% conf. Interval		Weight
				Low	Up	
Machado	2009	Brazil	0.455	0.421	0.489	0.67
Hasscl	2009	Italy	0.447	0.389	0.505	0.23
Hassc2	2009	Italy	0.458	0.400	0.516	0.23
Karkouti	2009	Canada	0.340	0.324	0.356	3.17
Hasse-fielits	2009	N/A	0.150	0.080	0.220	0.16
K-Han	2009	USA	0.400	0.299	0.501	0.08
Zappitelli	2009	Canada	0.359	0.311	0.407	0.34
Robert1	2010	New England	0.300	0.295	0.305	25.89
Robert2	2010	New England	0.310	0.304	0.316	24.14
Parikh	2010	Canada	0.050	0.038	0.062	5.28
MCIlorg	2010	USA	0.200	0.162	0.238	0.55
Shlipal	2011	USA	0.360	0.332	0.388	1.02
Englberg1	2011	USA	0.289	0.278	0.300	6.47
Englberg2	2011	USA	0.263	0.251	0.275	5.12
Krawezeski	2011	USA	0.272	0.213	0.331	0.23
Parolari	2012	Italy	0.089	0.079	0.099	8.12
Blinder	2012	USA	0.520	0.459	0.581	0.21
Bastin1	2013	UK	0.259	0.239	0.279	1.99
Bastin2	2013	UK	0.249	0.230	0.268	2.07
Mariscalco1	2013	Italy	0.095	0.084	0.106	6.03
Mariscalco2	2013	Italy	0.167	0.131	0.203	0.61
Machado	2014	Brazil	0.440	0.412	0.468	0.98
Meersth	2014	USA	0.520	0.382	0.658	0.04
ferreiro	2017	Uruguay	0.361	0.350	0.372	6.25
Romas	2018	Brazil	0.436	0.354	0.518	0.12
Pooled-ES	-----		0.263	0.261	0.266	100

Table 3.meta-analysis of the prevalence of AKI after cardiac surgery based on AKIN criteria

First author	Publication year	Country	Prevalence of AKI based on AKIN criteria			
			ES	95% conf. Interval		Weight
				Low	Up	
Machado	2009	Brazil	0.455	0.421	0.489	1.52
Hassc	2009	Italy	0.447	0.389	0.505	0.52
Hasse-fielits	2009	Italy	0.150	0.080	0.220	0.36
K-han	2009	USA	0.400	0.299	0.501	0.17
Robert	2010	New England	0.300	0.295	0.305	58.65
Mcilory	2010	USA	0.200	0.162	0.238	1.23
Shlipal	2011	USA	0.360	0.332	0.388	2.31
Englberger	2011	USA	0.263	0.251	0.275	11.59
Parolari	2012	Italy	0.089	0.079	0.099	18.39
Blinder	2012	USA	0.520	0.459	0.581	0.47
Bastin	2013	UK	0.259	0.239	0.279	4.51
Romas	2018	Brazil	0.436	0.354	0.518	0.27
Pooled ES	------		0.259	0.255	0.264	100

Table 4.meta-analysis of the prevalence of AKI after cardiac surgery based of RIFLE criteria

First author	Publication year	Country	Prevalence of AKI based of RIFLE criteria			
			ES	95% conf. Interval		Weight
				Low	Up	
Hassc	2009	Italy	0.458	0.40	0.516	0.53
Robert	2010	New England	0.310	0.304	0.316	55.70
Bastin	2013	UK	0.249	0.230	0.268	4.78
Mariscalco	2014	Italy	0.095	0.084	0.106	13.92
Mariscalco	2013	Italy	0.167	0.131	0.203	1.40
Karkouti	2009	Canada	0.340	0.324	0.356	7.32
Meersth	2014	USA	0.520	0.382	0.658	0.09
Englbeger	2011	USA	0.189	0.178	0.200	14.94
Zappitelli	2009	Canada	0.359	0.311	0.407	0.79
Krawezeski	2011	USA	0.272	0.213	0.331	0.52
Pooled ES	-----	-----	0.260	0.256	0.265	100

Table 5. meta-analysis of the prevalence of AKI after cardiac surgery based on KDIGO

First author	Publication year	Country	Prevalence of AKI based on KDIGO			
			ES	95% conf. Interval		Weight
				Low	Up	
Ferreiro	2017	Uruguay	0.361	0.350	0.372	67.79
Machado	2014	Brazil	0.440	0.412	0.468	10.62
Bastin	2013	UK	0.259	0.239	0.279	21.59
Pooled ES	------		0.347	0.338	0.357	100

Table 6. meta-analysis of the prevalence of AKI after pediatric cardiac surgery

First author	Publication year	Country	Prevalence of AKI after pediatric cardiac surgery			
			ES	95% conf. Interval		Weight
				Low	Up	
Zappitelli	2009	Canada	0.359	0.311	0.407	44.19
Blinder	2012	USA	0.520	0.459	0.581	26.81
Krawczeshki	2011	USA	0.272	0.213	0.331	29.00
Pooled ES	-----		0.375	0.345	0.409	100

Figures

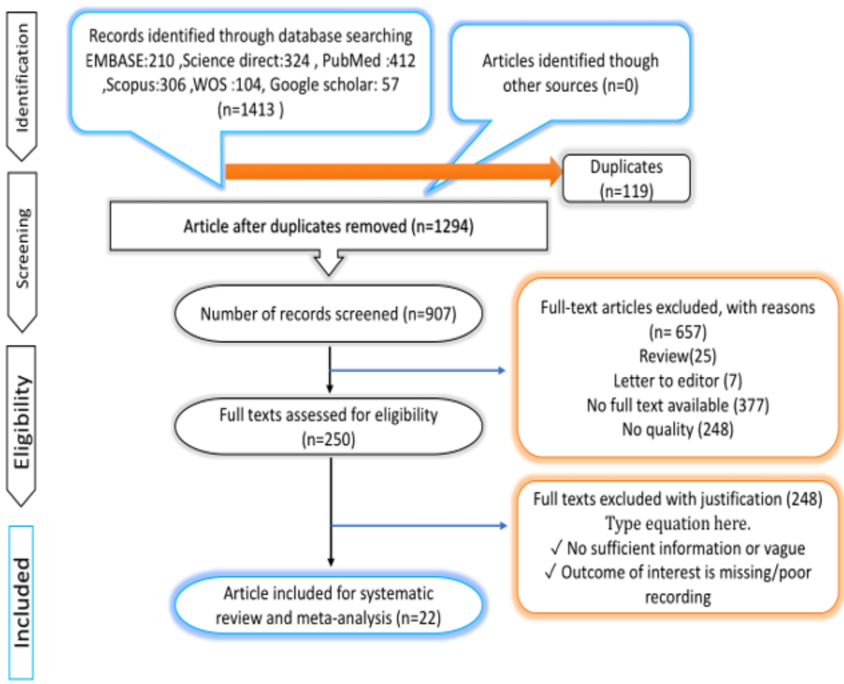

Figure 1

PRISMA flow diagram

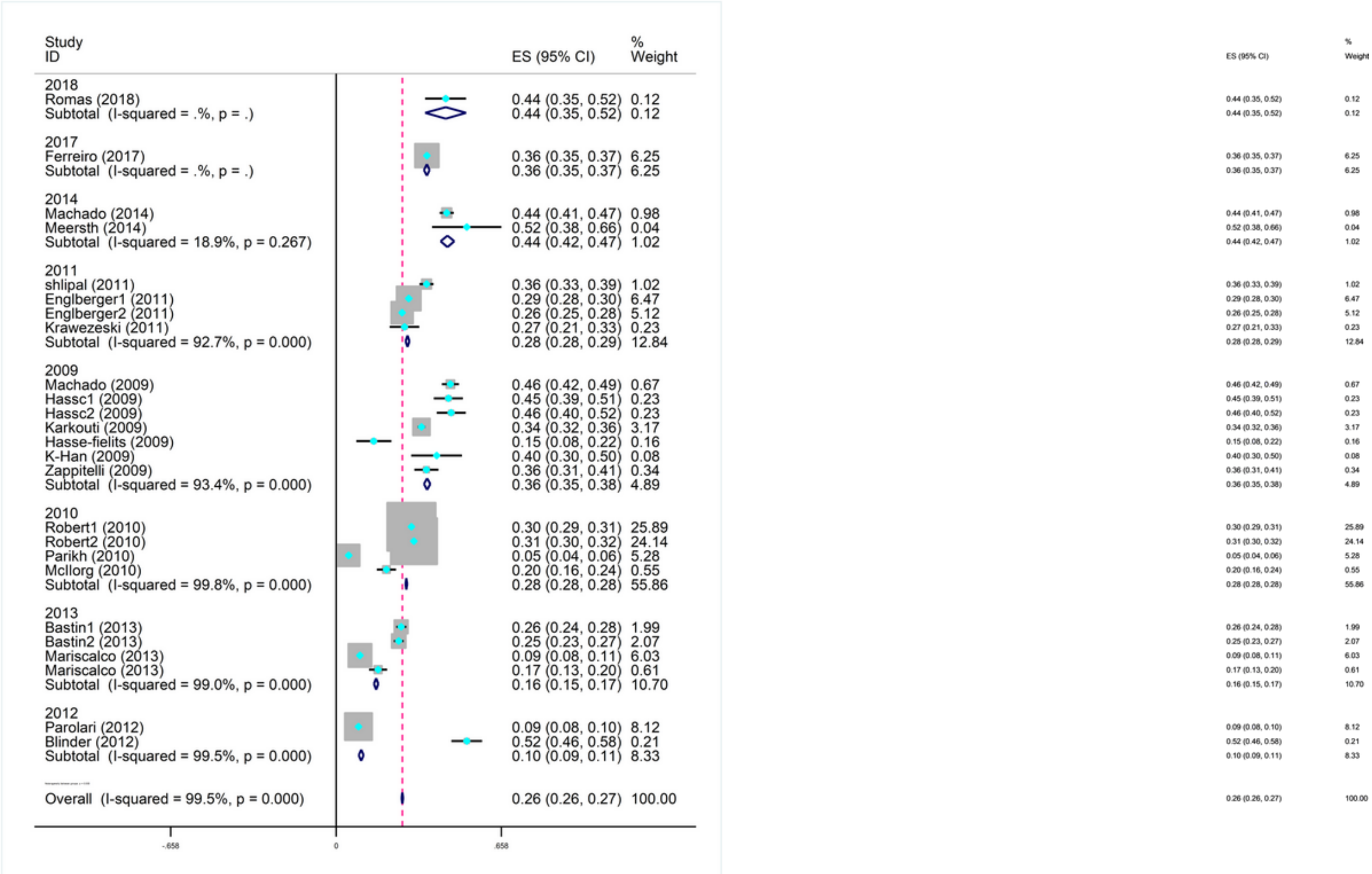

Figure 2

meta-analysis of the prevalence of AKI after cardiac surgery based on the year

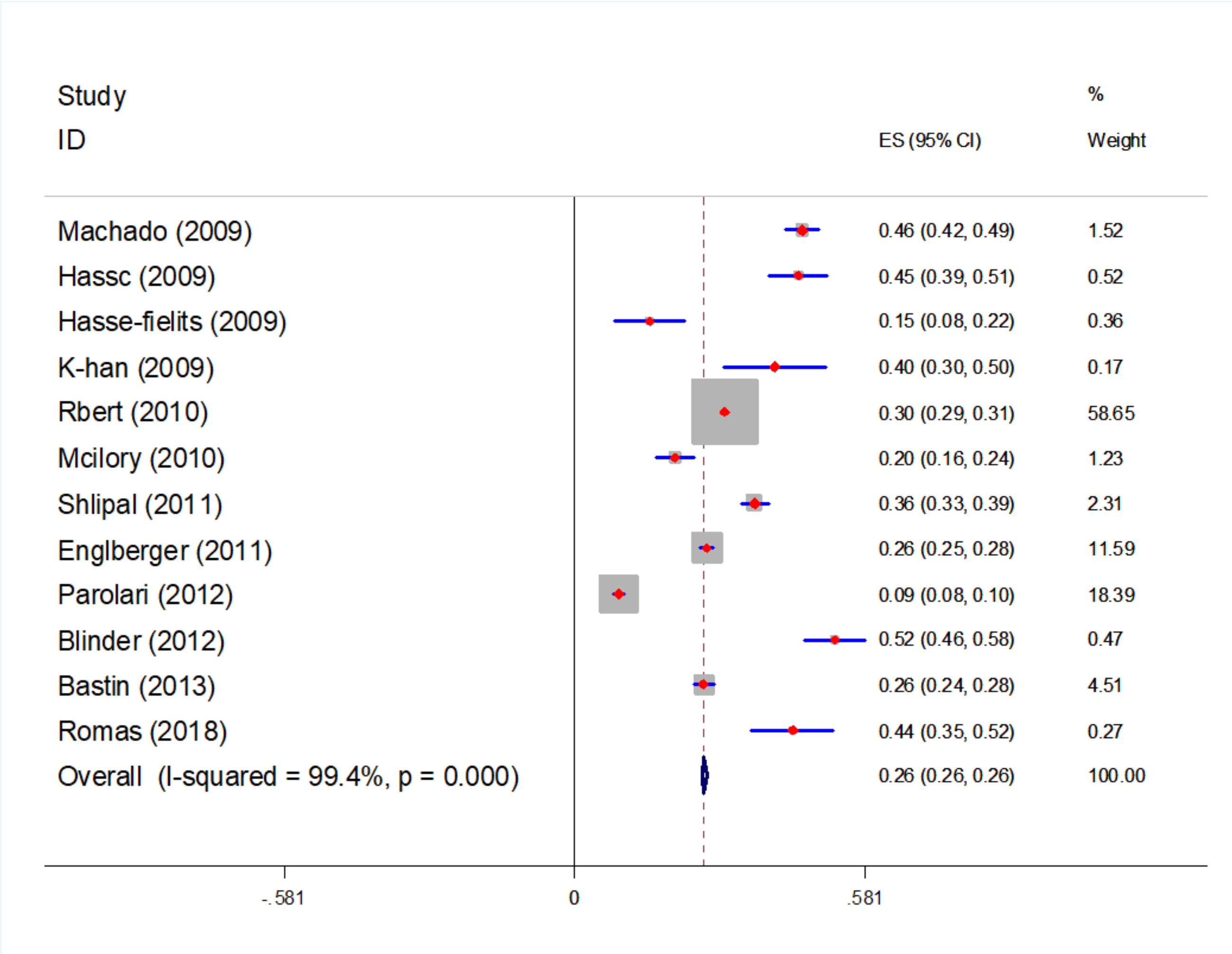

Figure 3

prevalence of AKI after cardiac surgery based on the AKIN criteria

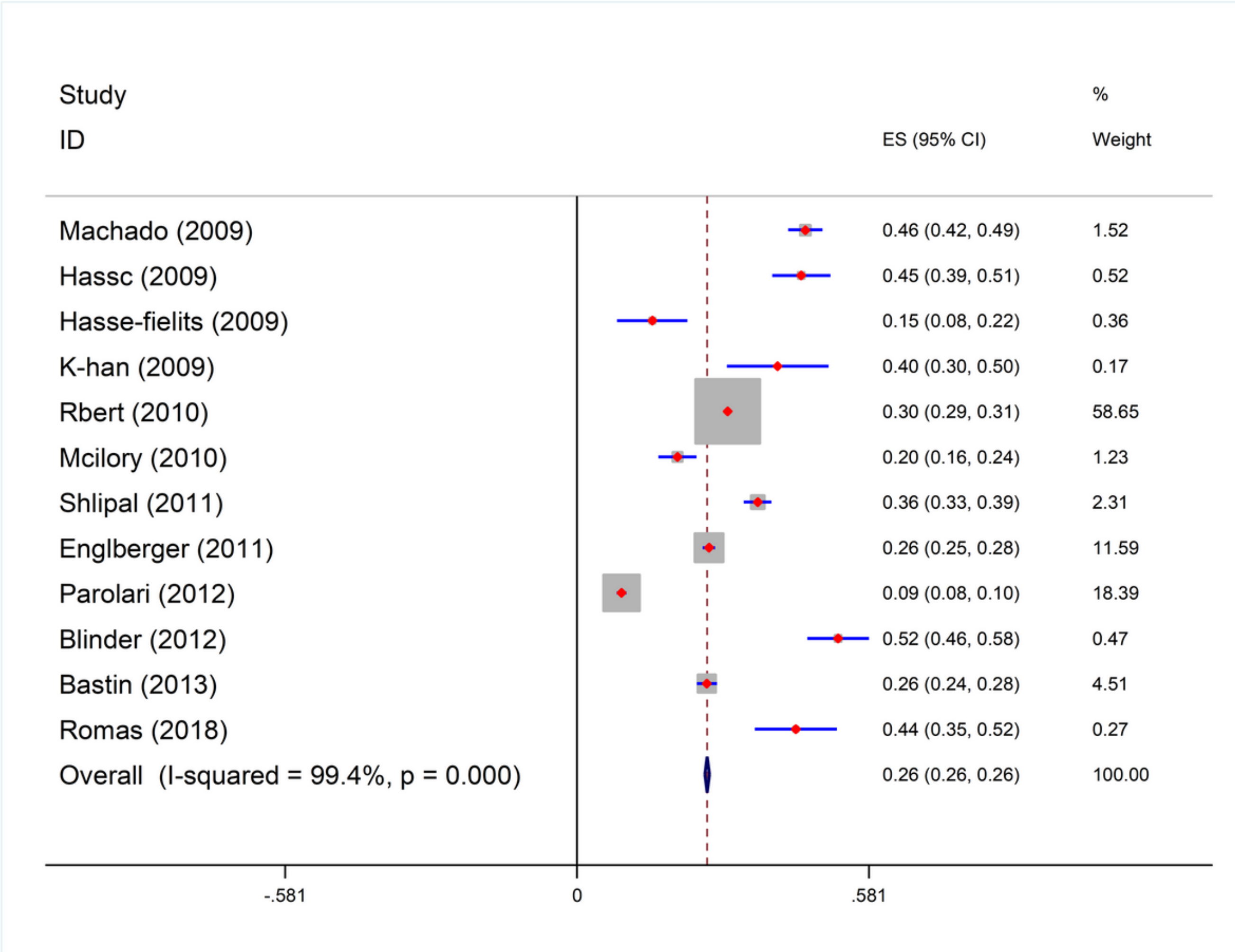

Figure 4

prevalence of AKI after cardiac surgery based on RIFLE criteria

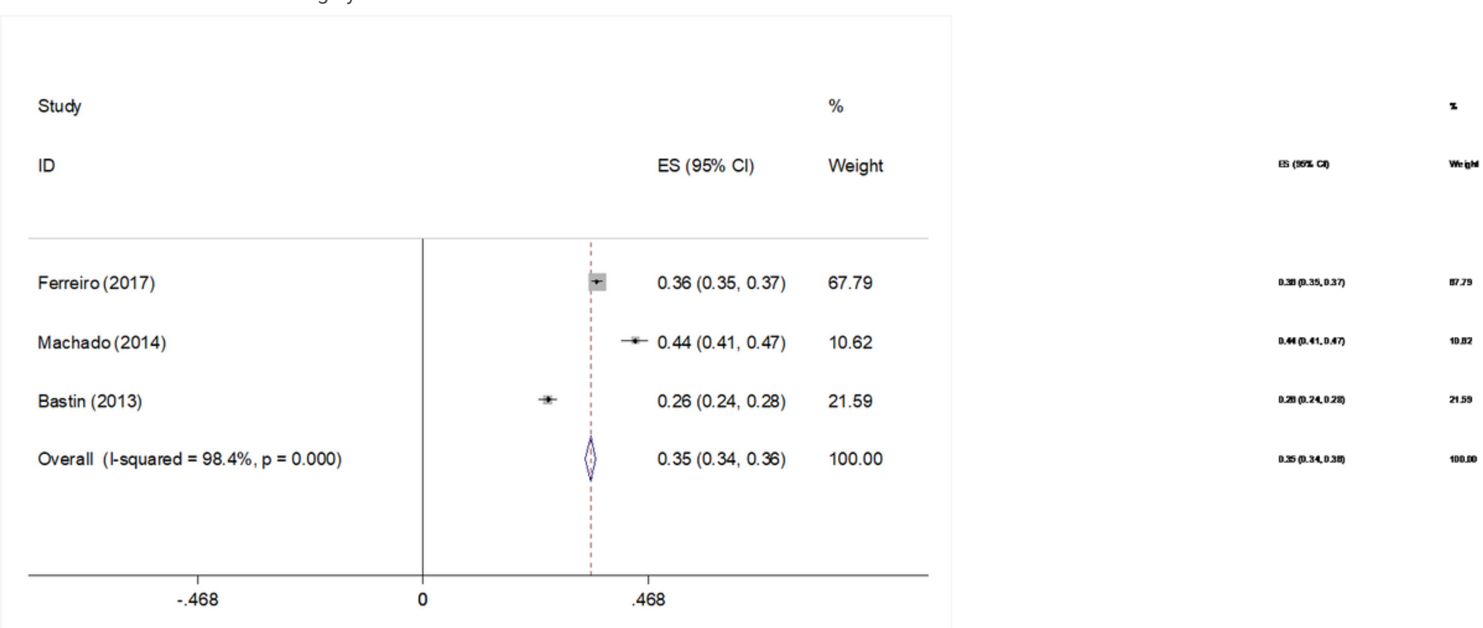

Figure 5

prevalence of AKI after cardiac surgery based on the KDIGO criteria

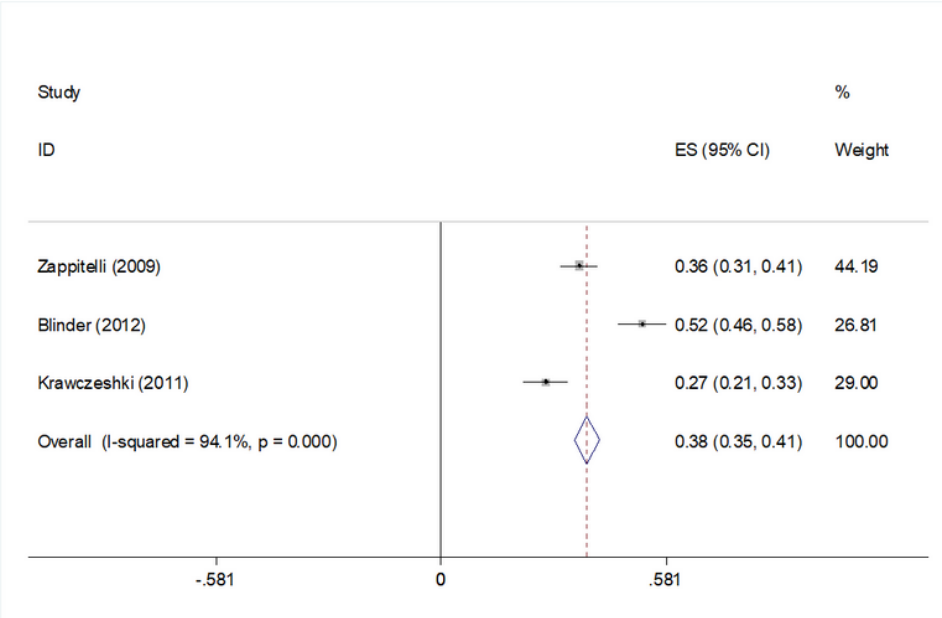

Figure 6

prevalence of AKI after pediatric cardiac surgery

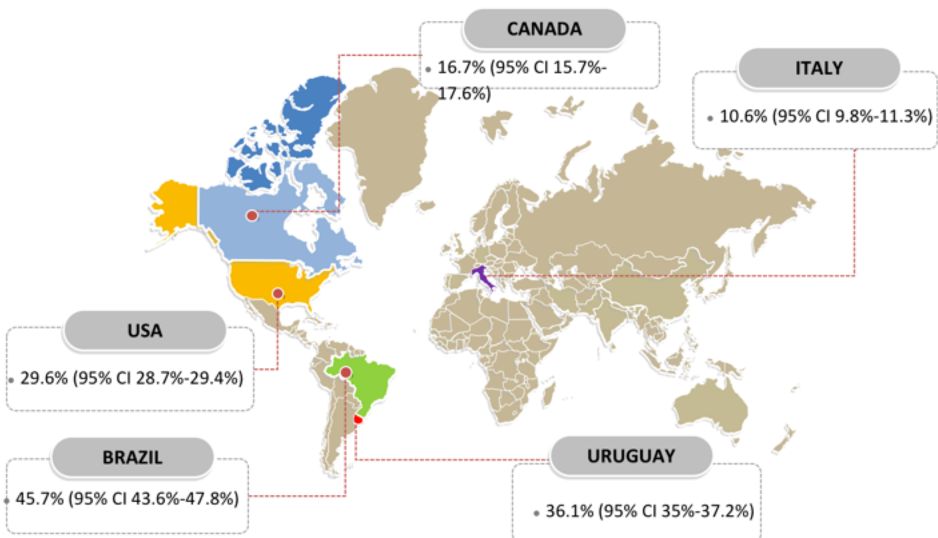

Figure 7

prevalence of AKI after cardiac surgery based on the country

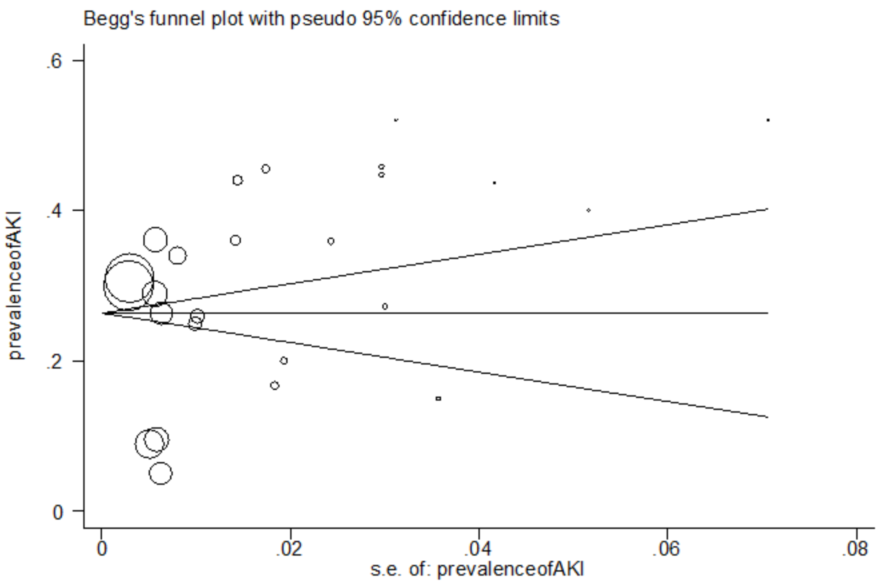

Figure 8

Funnel plot of publication bias shown in symmetrically.Circles' size shows the weight of studies (bigger circles show more samples and smaller circles show fewer samples).

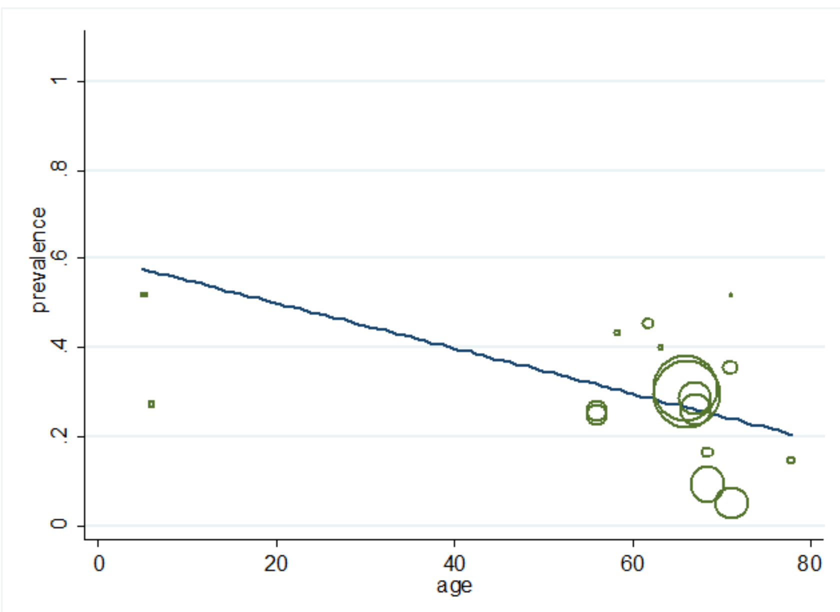

Figure 9

Meta-regression between age of the participants and prevalence of AKI after Cardiac surgery

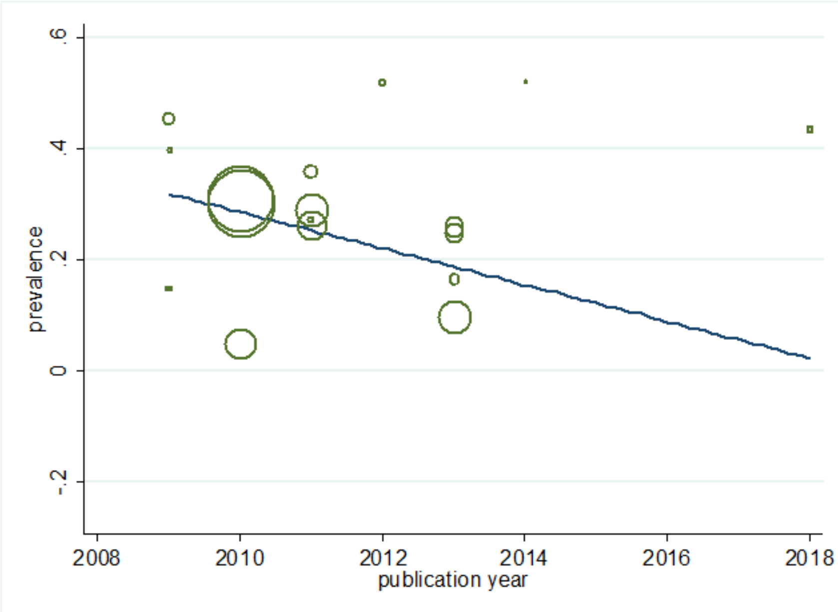

Figure 10

Meta-regression between publication year of study and prevalence of AKI after Cardiac surgery