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# Surgery or Endovascular Treatment, which is the Better Way to Treat Acute and Chronic Mesenteric Ischemia: Systematic Review and Meta-Analysis

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**Keywords:**

Mesenteric ischemia; Endovascular intervention; Open revascularization; Meta-analysis

## 1. Abstract

**1.1. Objective:** To investigate the influence of surgical and endovascular treatment on the prognosis of acute and chronic mesenteric ischemia and to further evaluate whether endovascular treatment can reduce postoperative complications by performing a meta-analysis.

**1.2. Methods:** We carried out a systematic literature search in three databases (PubMed, Embase, and Web of Science). All studies examining outcomes for patients undergoing endovascular intervention and open revascularization interventions for mesenteric ischemia were included.

**1.3. Results:** We summarized the available evidence from 25 studies with a total of 30,775 cases. The pooled results indicated that surgical intervention increases 30-day mortality (OR 1.45; 95% CI 1.08–1.95) and the incidence of postoperative pulmonary complications (OR: 1.61; 95% CI 1.28–2.04). However, this result seems to fit only in the subgroup with a large number of patients included.

**1.4. Conclusion:** The present study demonstrates that open surgery methods may increase the 30-day mortality in acute and chronic mesenteric ischemia and the incidence of postoperative pulmonary complications.

## 2. Introduction

Mesenteric ischemia (MI) occurs from insufficient blood flow to the gastrointestinal tract mucosa. MI is not a common cause of abdominal pain, and perhaps for this reason, delayed diagnosis and untimely treatment will lead to a grim prognosis. Chronic MI is the most common type of mesenteric vascular disorder, and it is often underdiagnosed in clinical practice [1]. For acute MI, the mortality is often as high as 50% to 70 % [2,4]. The treatment goal of MI is to restore vascular perfusion and minimize trauma [5]. Surgical intervention includes embolectomy and bypass graft, and endovascular revascularization is used to re-establish blood flow to the ischemic bowel [6], but the most appropriate treatment still remains unknown [7]. More importantly, there are no studies that have simultaneously evaluated appropriate treatment for acute and chronic MI. The present meta-analysis of current literature aimed to compare the perioperative outcomes among open surgery and endovascular approaches in patients with MI and identify the appropriate intervention.

## 3. Methods

### 3.1. Search Strategy

A comprehensive search from PubMed, EMBASE, and Web of Science databases was performed for articles published before November 2021. The terms (“mesenteric ischaemia” or “MI”) and (“revascularization” or “surgery” or “endovascular”) were searched. No language restrictions were imposed. References cited in the retrieved articles were also reviewed for relevant studies. Two reviewers (Liu-Jiang Li, Yong Yang) independently screened all candidate studies and discrepancies were resolved by consensus.

### 3.2. Selection and Exclusion Criteria

The inclusion criteria for each study were as follows: patients with a confirmed diagnosis of MI by duplex ultrasound or other imaging; patients with MI who had undergone endovascular or open surgical revascularization intervention; reported at least one of the outcomes of 30-day mortality, in-hospital complications. Studies were excluded in the current study: (1) The outcome of 30-day mortality or in-hospital complications in both treatments was zero; (2) animal studies, reviews, abstracts, letters, case reports and meetings reports, or full text not available; (3) duplicate articles; (4) studies including mesenteric venous thrombosis. A two-step selection process was used to identify eligible studies. Two independent reviewers (Lin-Juan Du, Zhen-Huan Ma) initially screened all titles and abstracts and then independent pairs of investigators screened full-text articles.

### 3.3. Data Extraction

Data were extracted independently by two investigators (Liu-Jiang Li, Guo-Jian Li), and disagreement was resolved by joint discussion. The data variables on first author, publication year, country, sample size, age of patients, comorbidities, type of intervention, and in-hospital outcomes were collected. The study quality was assessed with the Newcastle–Ottawa quality assessment scale (NOS). NOS scores of greater than or equal to 6 were regarded as high-quality studies.

### 3.4. Data Analysis

Outcomes were reported as risk ratio (RR) with 95% confidence interval (CI). Meta-analysis was conducted using STATA software. Statistical heterogeneity was assessed by the chi-squared and I-squared tests. if $I^2 \geq 50\%$ or/and $P < 0.10$, indicating substantial heterogeneity, random-effects model was used to calculate the pooled RR and 95% CI. Otherwise, a fixed-effect model was used. All statistical tests were two-sided, with $P < 0.05$ indicating statistical significance.

## 4. Results

### 4.1. Characteristics of Included Studies

We identified 208 articles from PubMed, EMBASE, and Web of Science. After exclusion of 3833 duplicates and 909 articles because they were not relevant to our research or did not meet our inclusion criteria by filtering titles or abstracts. We obtained 1916 full articles of potentially relevant studies. After full-text reviews, we excluded 1819 papers due to insufficient information. A detailed study selection flow chart is provided in Figure 1. We included 25 studies [8-33] with a total of 30,775 patients enrolled in this meta-analysis. These studies were mainly from the United States (19). The number of people included in each study spans a wide range, from 13 to 10,381. The basic characteristics of the included studies and detailed description of each study are summarized and presented in Table 1.

**Table 1**: Characteristics of the included studies.

| Author | Year | Number | Area | Age | Females (%) | Risk factors |
|---|---|---|---|---|---|---|
| Zientara | 2021 | 26 | Switzerland | 75(64–99) | 12 (46.1) | Arterial Hypertension Peripheral arterial disease Coronary arterial disease Diabetes COPD Dyslipidemia |
| Menges | 2020 | 63 | Germany | 71(60–76) | 42 (66.7) | Diabetes mellitus COPD Smoke Chronic kidney disease |
| Erben | 2018 | 10381 | USA | 69(18-98) | 6548（63.1） | Coronary artery disease Diabetes mellitus Chronic kidney disease |
| Zhang | 2017 | 30 | China | 61.9 | 10 (33.3) | Hypertension Peripheral arterial disease Diabetes Chronic kidney disease Smoke |
| Lima | 2017 | 1760 | USA | 66.2 | 1248(71) | Arterial Hypertension Peripheral arterial disease Coronary arterial disease Diabetes Dyslipidemia COPD |
| Arya | 2016 | 34 | USA | 64 | 25(73.5) | Coronary artery disease Diabetes mellitus Chronic kidney disease Smoke |
| Eslami | 2016 | 1563 | USA | 68.7 | 1016(65) | Peripheral arterial disease Diabetes mellitus Chronic kidney disease COPD |
| Arya | 2016 | 81 | USA | 64 | 65 (80.2) | Arterial Hypertension Peripheral arterial disease Coronary arterial disease Diabetes Dyslipidemia COPD |
| Zacharias | 2016 | 161 | USA | 69 | 116 (72) | Hypertension Coronary artery disease Diabetes mellitus COPD Smoke |
| Branco | 2015 | 439 | USA | | 172(39.2) | Diabetes mellitus Chronic kidney disease COPD Smoke |
| Barret | 2015 | 54 | France | 66.3 | 33 (61.1) | Hypertension Coronary artery disease Diabetes mellitus COPD Smoke |
| Beaulieu | 2014 | 4665 | USA | 70.5 | 2664(57.1) | Arterial Hypertension Peripheral arterial disease Diabetes Dyslipidemia COPD |
| Jia | 2014 | 21 | China | 71 | 6 (28.6) | NA |
| Kanamori | 2014 | 47 | USA | 58 | 42 (89.4) | Hypertension Diabetes mellitus Chronic kidney disease COPD Smoke |
| Ryer | 2012 | 93 | USA | 68 | 58 (62.4) | NA |
| Arthurs | 2011 | 70 | USA | 64 | 20 (28.6) | Arterial Hypertension Peripheral arterial disease Coronary arterial disease Diabetes Dyslipidemia COPD Smoke |
| Block | 2010 | 161 | Sweden | 76(65-82) | 90 (55.9) | Ischemic heart disease Cerebrovascular disease Diabetes Smoke |
| Rawat | 2010 | 76 | USA | 65(40-86) | 54 (71.1) | Ischemic heart disease Transient ischemic attack Diabetes mellitus Smoke |
| Schermerhorn | 2009 | 5237 | USA | NA | 3531 (67.4) | Arterial Hypertension Peripheral arterial disease Coronary arterial disease Diabetes Dyslipidemia COPD |

| | | | | | | |
|---|---|---|---|---|---|---|
| Davies | 2009 | 32 | USA | 70 | 19 (59.4) | Hypertension Peripheral vascular disease Diabetes mellitus Smoke COPD |
| Schermerhorn | 2009 | 5583 | USA | NA | 3857 (69.1) | Hypertension Coronary artery disease Diabetes mellitus COPD Smoke |
| Zerbib | 2008 | 29 | France | NA | 12 (41.2) | Hypertension Coronary artery disease Diabetes mellitus Smoke |
| Wyers | 2007 | 13 | Lebanon | NA | NA | NA |
| Atkins | 2007 | 80 | USA | 65 | 33 (41.3) | NA |
| Sivamurthy | 2006 | 60 | USA | 66 | 44 (73.3) | Hypertension Transient ischemic attack Myocardial infarction Congestive heart failure Diabetes mellitus Smoke |
| Brown | 2005 | 47 | USA | 73 | 37 (78.7) | Hypertension Diabetes mellitus Chronic kidney disease COPD Smoke |
| Kasirajan | 2001 | 113 | Canada | NA | 81 (71.7) | Hypertension Diabetes mellitus Chronic kidney disease COPD smoke |
| Rose | 1995 | 17 | USA | NA | NA | NA |

### 4.2. Quality Assessment

All the available studies were retrospective. Most of the studies showed low risk of bias in terms of selection of study participants, ascertainment of exposure, control for confounding, and ascertainment of outcome. Overall judgment of the risk of bias was mostly low risk. The risk of bias assessment of each included study is shown in detail in Supplementary Table 2.

### 4.3. Outcomes of Interest

**4.3.1. Thirty-Day Mortality:** All of the studies reported the 30-day mortality. Random-effects model was used to pool all the included studies and demonstrated that surgical intervention increased the risk of 30-day mortality (OR 1.45; 95% CI 1.08–1.95; Figure 2) with inter-study heterogeneity ($I^2 = 96.7\%$, $P < 0.001$). Because of the high $I^2$ and P values in the pooled analysis, subgroup analyses were also performed. In the subgroup with less than 100 patients included in the study, the 30-day mortality rate for open surgery and endovascular intervention was similar to that in studies with larger populations. We analyzed several possible sources of heterogeneity and the results are summarized in Table 2. After the introduction of the regression model with the four factors, the number of people included in the study may be a source of heterogeneity following meta-regression.

**4.3.2. Pulmonary Complications:** There were 13 studies reporting pulmonary complications. Open surgery was associated with an increased risk of pulmonary complications (OR: 1.61; 95% CI 1.28–2.04; Figure 3) with a random-effects model. In the subgroup of acute MI and the subgroup with more than 100 patients enrolled in the study, open surgery increased postoperative pulmonary complications. After the introduction of the regression model with the four factors, we determined that the number of patients included in the study and whether MI was acute or chronic may be sources of heterogeneity following meta-regression (Table 3).

**Supplementary Table:** Studies Quality Evaluation Form

| author | Year | Selection of studies | Ascertainment of exposure | control of confounding | Assessment of outcome | Was Follow-Up Long Enough for Outcomes to Occur | Overall |
|---|---|---|---|---|---|---|---|
| Zientara | 2021 | 1 | 1 | 1 | 1 | 1 | High quality |
| Menges | 2020 | 1 | 1 | 1 | 1 | 1 | High quality |
| Erben | 2018 | 1 | 1 | 1 | 1 | 1 | High quality |
| Zhang | 2017 | 1 | 1 | 1 | 1 | 1 | High quality |
| Lima | 2017 | 1 | 1 | 1 | 1 | 1 | High quality |
| Arya | 2016 | 1 | 1 | 1 | 1 | 1 | High quality |
| Zacharias | 2016 | 1 | 1 | 1 | 1 | 1 | High quality |
| Arya | 2016 | 1 | 1 | 1 | 1 | 1 | High quality |
| Eslami | 2016 | 1 | 1 | 1 | 1 | 1 | High quality |
| Branco | 2015 | 1 | 1 | 1 | 1 | 1 | High quality |
| Barret | 2015 | 1 | 1 | 1 | 1 | 1 | High quality |
| Beaulieu | 2014 | 1 | 1 | 1 | 1 | 1 | High quality |
| Jia | 2014 | 1 | 1 | 0 | 1 | 1 | Low quality |
| Kanamori | 2014 | 1 | 1 | 1 | 1 | 1 | High quality |
| Ryer | 2012 | 1 | 1 | 0 | 1 | 1 | Low quality |
| Arthurs | 2011 | 1 | 1 | 1 | 1 | 1 | High quality |
| Block | 2010 | 1 | 1 | 1 | 1 | 1 | High quality |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Rawat | 2010 | 1 | 1 | 1 | 1 | 1 | High quality |
| Davies | 2009 | 1 | 1 | 1 | 0 | 1 | Low quality |
| Schermerhorn | 2009 | 1 | 1 | 1 | 1 | 1 | High quality |
| Schermerhorn | 2009 | 1 | 1 | 1 | 1 | 1 | High quality |
| Zerbib | 2008 | 1 | 1 | 1 | 1 | 1 | High quality |
| Wyers | 2007 | 1 | 1 | 0 | 1 | 1 | Low quality |
| Atkins | 2007 | 1 | 1 | 0 | 1 | 1 | Low quality |
| Sivamurthy | 2006 | 1 | 1 | 1 | 1 | 1 | High quality |
| Brown | 2005 | 1 | 1 | 1 | 1 | 1 | High quality |
| Kasirajan | 2001 | 1 | 1 | 1 | 1 | 1 | High quality |
| Rose | 1995 | 1 | 1 | 0 | 0 | 1 | Low quality |

**Table 2**: Subgroup analysis and meta-regression analysis for the studies assess the influence of treatment in 30-day mortality of MI.

| Covariates | Subgroup | No. of studies | OR (95% CI) | | Heterogeneity | | Meta-regression P |
|---|---|---|---|---|---|---|---|
| | | | Random-effects model | Fixed-effects model | P | $I^2$ | |
| Overall | | 25 | 1.45(1.08,1.95) | | <0.001 | 96.7% | |
| Area | others | 7 | 1.75(0.87,3.53) | 2.27(2.1,2.47) | <0.001 | 97.8% | 0.407 |
| | USA | 18 | 1.30(1.06,1.58) | 1.00(0.95,1.05) | <0.001 | 86.1% | |
| Year | Last 5 years | 7 | 1.74(1.11,2.73) | 1.06(0.98,1.14) | <0.001 | 97.8% | 0.365 |
| | others | 18 | 1.32(0.89,1.95) | 1.51(1.30,1.76) | <0.001 | 86.1% | |
| numbers | <100 | 16 | 0.94(0.90,0.99) | 0.94(0.90,0.99) | 0.44 | 1.1% | <0.001 |
| | >100 | 9 | 2.46(1.62,3.74) | 3.31(3.03,3.61) | <0.001 | 92.2% | |
| Type of MI | Acute | 13 | 1.68(1.01,2.82) | 2.41(2.23,2.61) | <0.001 | 96.2% | 0.202 |
| | Chronic | 12 | 1.05(0.92,1.20) | 0.96(0.92,1.01) | <0.001 | 69.4% | |

**Table 3**: Subgroup analysis and meta-regression analysis for the studies assess the influence of treatment in pulmonary complications of MI.

| Covariates | Subgroup | No. of studies | OR (95% CI) | | Heterogeneity | | Meta-regression P |
|---|---|---|---|---|---|---|---|
| | | | Random-effects model | Fixed-effects model | P | $I^2$ | |
| Overall | | 13 | 1.61(1.28,2.04) | | <0.001 | 95.7% | |
| Area | others | 7 | 1.57 (0.58,4.26) | 0.96(0.87,1.05) | 0.148 | 47.7% | 0.896 |
| | USA | 18 | 1.76(1.33,2.33) | 0.99(0.96,1.02) | <0.001 | 95.7% | |
| Year | Last 5 years | 3 | 0.92(0.86,0.99) | 0.92(0.86,0.98) | 0.326 | 10. 8% | 0.29 |
| | others | 10 | 2.11(1.49,3.00) | 1.00(0.97,1.04) | <0.001 | 95.7% | |
| numbers | <100 | 9 | 0.93(0.86,1.02) | 0.96(0.93,0.99) | 0.001 | 69.2% | <0.001 |
| | >100 | 4 | 5.02(2.48,10.17) | 6.78(5.30,8.66) | 0.001 | 80.7% | |
| Type of MI | Acute | 5 | 4.85(2.60,9.05) | 2.41(2.23,2.61) | 0.02 | 76.2% | <0.001 |
| | Chronic | 8 | 6.64(5.22,8.45) | 0.96(0.93,0.98) | <0.001 | 95.7% | |

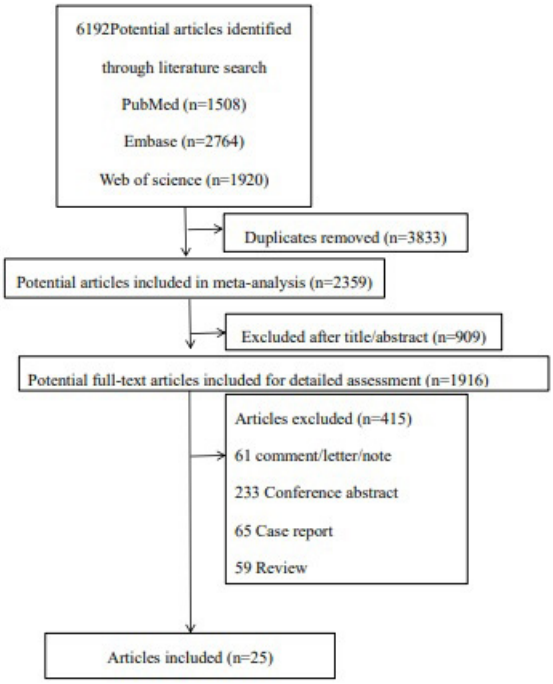



**Figure 1:** Flow chart of literature search and study selection.

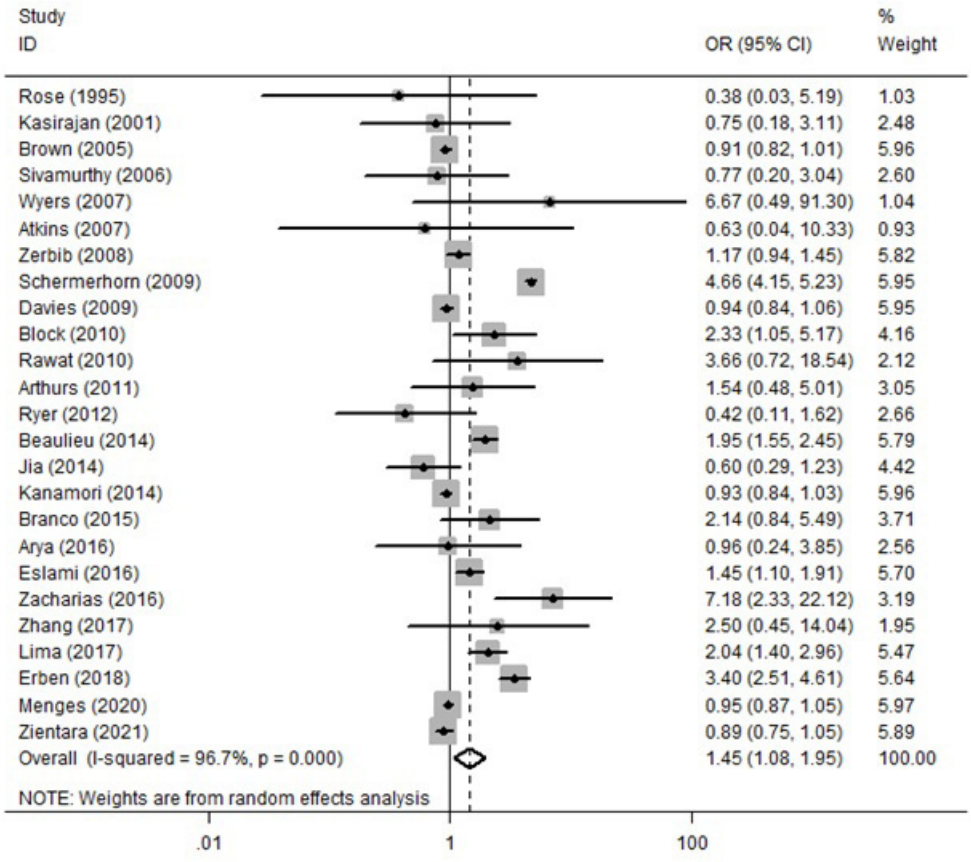



**Figure 2:** Forest plots depicting 30-day mortality rate of different treatments. OR was shown with 95% CI. CI: confidence interval.

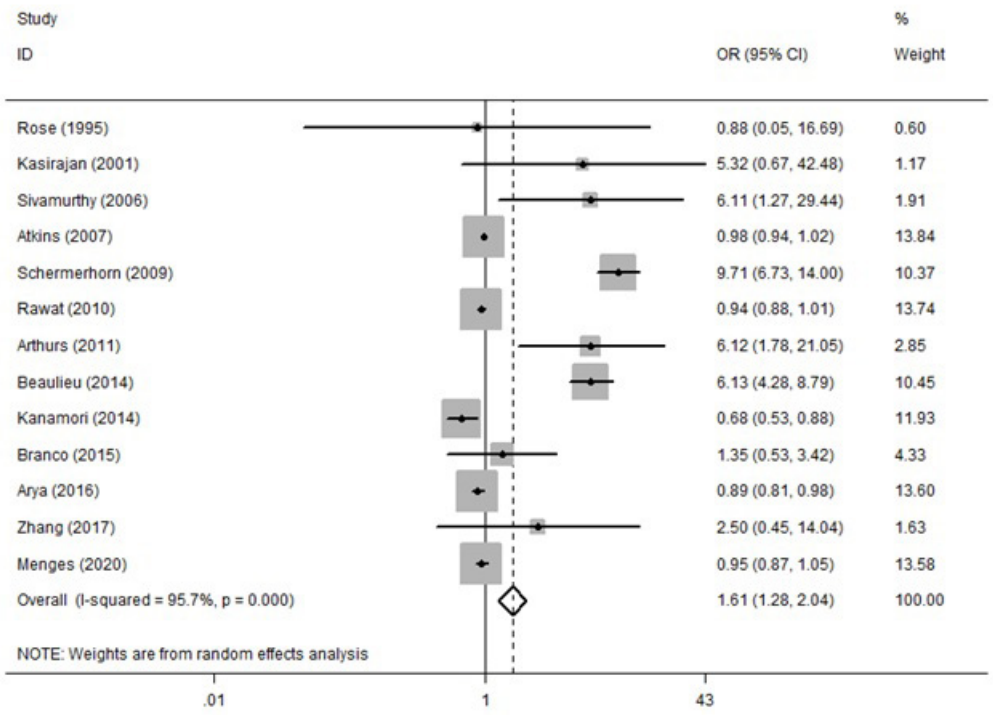



**Figure 3:** Forest plots depicting pulmonary complications of different treatments.

**4.3.3. Renal Complications:** There was no statistically significant difference in renal complications between the open surgical intervention and the endovascular approach (OR: 1.08; 95% CI 0.93–1.26; Figure 4). Although we performed subgroup analysis and regression, no source of heterogeneity was found (Table 4).

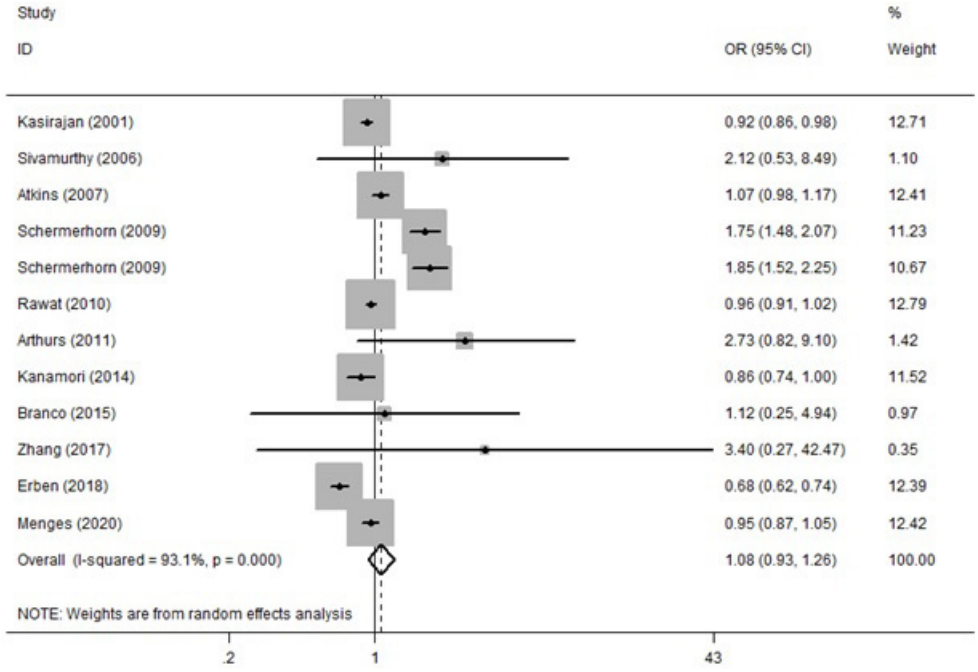
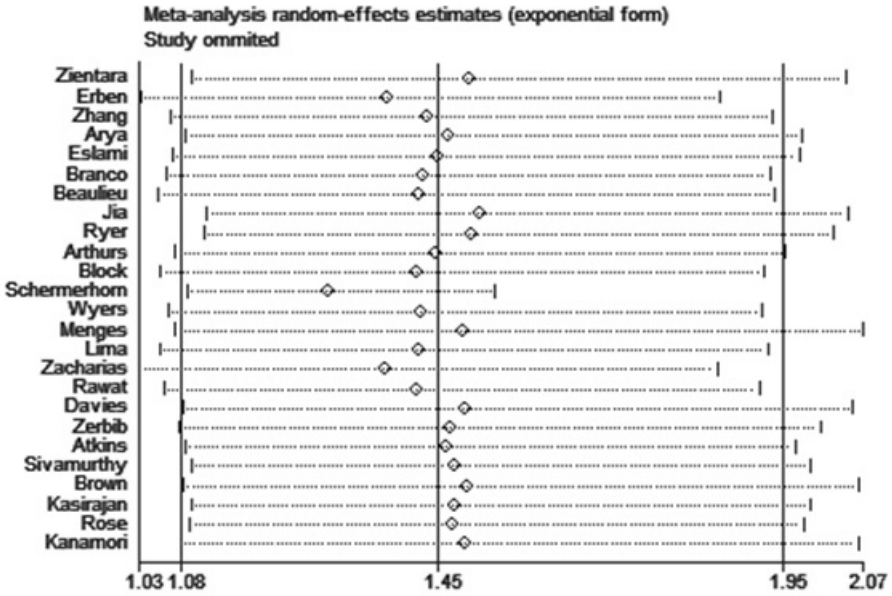



**Figure 4:** Forest plots depicting risk of renal complications of different treatments.

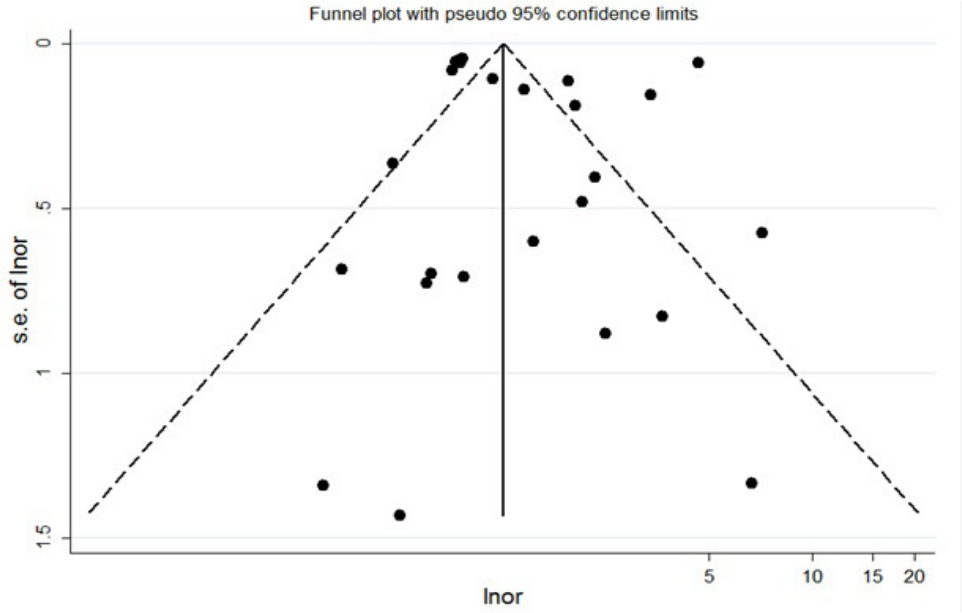
**Table 4**: Subgroup analysis and meta-regression analysis for the studies assess the influence of treatment in renal complications of MI.

| Covariates | Subgroup | No. of studies | OR (95% CI) | | Heterogeneity | | Meta-regression P |
|---|---|---|---|---|---|---|---|
| | | | Random-effects model | Fixed-effects model | P | $I^2$ | |
| Overall | | 12 | 1.08(0.93,1.26) | | <0.001 | 93.1% | |
| Area | others | 3 | 0.93 (0.88,0.98) | 0.93 (0.88,0.98) | 0.474 | 0 | 0.539 |
| | USA | 9 | 1.15(0.92,1.45) | 0.97(0.94,1.01) | <0.001 | 94.9% | |
| Year | Last 5 years | 3 | 0.82(0.59,1.15) | 0.81(0.76,0.86) | <0.001 | 92.8% | 0.168 |
| | others | 9 | 1.18(1.00,1.39) | 1.00(0.97,1.04) | <0.001 | 91.9% | |
| numbers | <100 | 7 | 0.98(0.90,1.05) | 0.97(0.94,1.01) | <0.001 | 97.3% | 0.718 |
| | >100 | 5 | 1.18(0.81,1.72) | 0.93(0.89,0.98) | 0.061 | 50.2% | |
| Type of MI | Acute | 5 | 1.38(0.66,2.86) | 0.86(0.79,0.93) | <0.001 | 96% | 0.639 |
| | Chronic | 7 | 1.04(0.93,1.17) | 0.98(0.94,1.01) | <0.001 | 88.5% | |

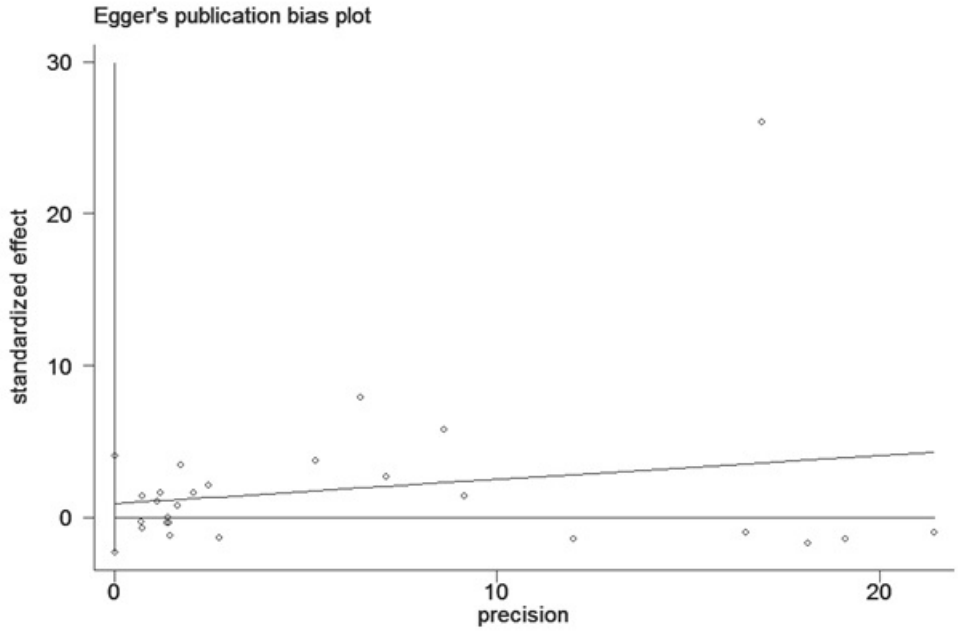
**4.3.4. Sensitivity Analysis and Publication Bias:** Influence analysis was performed and demonstrated that no one study could overly affect the summary of the outcomes estimate (Supplementary Figure 1). Publication bias was assessed by funnel plot analysis and the plots showed basic symmetry (Supplementary Figure 2). No significant publication bias was further determined by Begg's test (Supplementary Figure 3).




**Supplementary Figure. 1:** Influence analysis for the studies.




**Supplementary Figure 2**: Funnel plot of comparison of the included trials.




**Supplementary Figure 3:** Begg's test result of publication bias.

## 5. Discussion

MI has no distinguishing clinical manifestations and is often misdiagnosed [34]. With the advancements in diagnosis and treatment technology, MI has become a multidisciplinary disease and is currently treated mainly through open surgery and interventional management. However, the optimal management of MI remains controversial [13,35,36]. The best treatments for MI, acute MI, and chronic MI have only been meta-analyzed separately. For the first time, we have comprehensively evaluated the treatment of two types of MI. Our meta-analysis included 28 articles, including 30775 patients with MI, and showed that patients treated with open surgery have an increased rate of 30-day mortality (OR 1.45; 95% CI 1.08–1.95) and incidence of pulmonary complications (OR: 1.61; 95% CI 1.28–2.04), especially in studies involving more than 100 patients. When more than 100 patients were enrolled, open surgery also significantly increased the incidence of postoperative pulmonary complications. The open surgery approach is a traditional treatment method for MI. In recent years, endovascular treatment has been more popular because it avoids laparotomy [37]. With regard to 30-day mortality, although the short-term mortality in patients with chronic MI and acute MI is very different, open surgery may have a worse prognosis. This is consistent with previous research results [38,39], although exact reasons for this remain unclear. This may be caused by bias in the selection of interventions. Patients with mild symptoms or potential intestinal ischemia but not intestinal necrosis are usually selected for endovascular interventional therapy. Open surgery interferes greatly with abdominal organs, and abdominal incisions are also not conducive to patient recovery. However, this conclusion is applicable only to studies with a large number of patients (more than 100), as we found in this study. Research with a large sample size is needed to explore this finding further. Open surgery increased the rate of lung complications compared with endovascular therapy. This may be because open surgery needs to be performed under general anesthesia and endotracheal intubation with general anesthesia may interfere with the respiratory system, while the intravascular intervention requires only local anesthesia. In the subgroup analysis, the increase in pulmonary complications by open surgery seems to apply only to acute MI and studies including more than 100 patients. MI reperfusion injury may induce remote organ injuries [40,41]; the lung appears to be the first organ affected by this pathogenic process [42]. In patients with chronic MI, the body may adapt to the ischemic state because of long-term circulatory blockage, and the damage during reperfusion is relatively light. Of course, the influence of large sample size and high-quality research on the conclusion is obvious.

The rate of bowel resection was not statistically different in different treatment methods of our study. This is inconsistent with the conclusions of previous studies [43]. This may be related to requiring laparotomy to remove the necrotic bowel after endovascular treatment [44]. There was no significant difference in renal complications in the different treatment studies in our study. There were also no significant differences in the different subgroups with respect to number of patients included, different regions, and acute and chronic MI. This is inconsistent with the study of Davenport et al [45]. Although intravascular interventional therapy produces mild hemodynamic changes, contrast-induced acute kidney injury cannot be ignored.

## 6. Limitations

There are several limitations in our meta-analysis. First, there is obvious heterogeneity in our meta-analysis. Although sensitivity analysis, subgroup analysis, and meta-regression were used, high

heterogeneity existed among studies. Second, all the included studies were retrospective studies, so the representativeness of our study may be limited. Third, most of the studies we included were from the United States, and the conclusions reached may be geographically restricted. Fourth, most of the studies analyzed included a small number of patients, and this may not represent the actual efficacy.

## 7. Conclusions

Endovascular approach for AMI may be associated with decreased 30-day mortality and avoidance of the incidence of postoperative pulmonary complications. However, more high-quality studies with larger sample sizes are warranted.

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