Short-term outcomes of on- vs off-pump coronary artery bypass grafting in patients with left ventricular dysfunction: a systematic review and meta-analysis

Zhiyuan Guan 1, Xiaoqing Guan 2, Kaiyun Gu 1, Xuanqi Lin 3, Jin Lin 1, Wenjun Zhou 1, Ming Xu 4, Fen Wan 5, Zhe Zhang 1* and Chunli Song 6*

Abstract

Objectives: Does the manipulation of the off-pump CABG (OPCAB) in patient with depressed left ventricular function is better than on-pump CABG (ONCAB) approach in in-hospital mortality and morbidities? Here we undertook a meta-analysis of the best evidence available on the comparison of primary and second clinical outcomes of the off-pump and on-pump CABG.

Design: Systematic literature reviewer and meta-analysis.

Data sources: PubMed, EMBASE, Web of science and Cochrane Center Registry of Controlled Trials were searched the studies which comparing the use of the off-pump CABG(OPCAB) and on-pump CABG (ONCAB) for patients with LVD during January 1990.1 to January 2018.

Eligibility criteria: All observation studies and randomized controlled trials comparing on-pump and off-pump as main technique for multi-vessel coronary artery disease (defined as severe stenosis (>70%) in at least 2 major diseased coronary arteries) with left ventricular dysfunction(defined as ejection fraction (EF) 40% or less) were included.

Data extraction and synthesis: Authors will screen and select the studies extract the following data, first author, year of publication, trial characters, study design, inclusion and exclusion criteria, graft type, clinical outcome, assess the risk of bias and heterogeneity. Study-specific estimates will pool through the modification of the Newcastle-Ottawa scale for the quality of study and while leave-one-out analysis will be used to detect the impact of individual studies on the robustness of outcomes.

(Continued on next page)
Introduction

The impresses left ventricular function is important risk factors to effect the clinical outcome of coronary artery bypass surgery. Several meta-analysis has been performed that investigated the short-term and long-term clinical prognosis of on-pump versus off-pump CABG [1, 2]. Topkara et.al found that in-hospital mortality and morbidities were significantly higher in patients underwent CABG with depressed LV function than normal LV function [3]. For patient with lower left ventricular function, comparing medical therapy with CABG for patients with symptomatic coronary artery disease and ejection fraction (EF) as low as 30% have shown a long-term survival benefit for those receiving CABG [4].

The CABG focus on long term benefits compared with medical treatment of coronary artery disease in patients with lower left ventricular function [5] and up to 15% of patients present with severely depressed left ventricular function [6]. Due to the improved technique and LVAD/ECMO led to progressively improved CABG clinical outcome in recent years. On the other hand, it has been suggested that off-pump CABG may be beneficial in patients with severely depressed LV function by avoiding prolonged ischemic times. In the 2011, Jarrel OA et.al [7] has been aggregated meta-analysis which has focused on the comparison of clinical results of the CABG, especially in patients with LVD show that off-pump CABG may be associated with lower incidence of early mortality in patient with LVD. Therefore, the advantages of off-pump compared with conventional on-pump CABG in patients with LVD remain a source of controversy. On this background, the aim of this systematic review was to synthesize the results from all studies reporting the short-term clinical outcome that investigated on- versus off-pump CABG in patients with LVD.

Methods

This systematic review and meta-analysis follow the preferred reporting items for systematic reviews and meta-analysis statement.

Search strategy and definition

A medical librarian developed searches to identify studies that compared the clinical outcome between on-pump and off-pump CABG. PubMed, EMBASE, Web of science and Cochrane Center Registry of Controlled Trials were searched during January 1990.1 to January 2018. Searches used subject headings and keywords for the following terms: ‘coronary artery bypass, off-pump, on-pump, left ventricular dysfunction, cardiopulmonary bypass, CABG.’(Supplement 1 search strategy).

To be eligible for inclusion in our meta-analysis, trials had to conform to the following criteria: the observation studies comparing on-pump and off-pump as main technique for multivessel coronary artery disease (defined as severe stenosis (>70%) in at least 2 major diseased coronary arteries) with left ventricular dysfunction(defined as ejection fraction 40% or less). Animal studies, review papers were excluded. Studies that did not have any of the desired outcome measures or participants who were treated by other modalities such as percutaneous coronary intervention and emergency or salvage conditions were excluded. Incomplete data were excluded. Studies that included interventions other than off-pump versus on-pump CABG were excluded.

Data extractions and quality assessment

Three reviewers (Guan; Gu; Lin) independently extracted the following data from each study, first author, year of publication, trial characteristics, study design, inclusion and exclusion criteria, graft type, clinical outcome (Fig. 1). The following variables were included:

Results: Among the 987 screened articles, a total of 16 studies (32,354 patients) were included. A significant relationship between patient risk profile and benefits from OPCAB was found in terms of the 30-day mortality (odds ratio [OR], 0.84; 95% confidence interval [CI], 0.73–0.97; P = 0.02), stroke (OR, 0.69; 95% CI, 0.55–0.86; P = 0.00), myocardial infarction (MI) (OR, 0.71; 95% CI, 0.53–0.96; P = 0.02), renal failure (OR, 0.71; 95% CI, 0.55–0.93; P = 0.01), pulmonary complication (OR, 0.68; 95% CI, 0.52–0.90; P = 0.01), infection (OR, 0.67; 95% CI, 0.49–0.91; P = 0.00), postoperative transfusion (OR, 0.25; 95% CI, 0.08–0.84; P = 0.02) and reoperation for bleeding (OR, 0.56; 95% CI, 0.41–0.75; P = 0.00). There was no significant difference in atrial fibrillation (AF) (OR, 0.96; 95% CI, 0.78–1.41; P = 0.56) and neurological dysfunction (OR, 0.88; 95% CI, 0.49–1.57; P = 0.65).

Conclusions: Compared with the on-pump CABG with LVD, using the off-pump CABG is a better choice for patients with lower mortality, stroke, MI, RF, pulmonary complication, infection, postoperative transfusion and reoperation for bleeding. Further randomized studies are warranted to corroborate these observational data.

Keywords: On-pump, Off-pump, Left ventricular dysfunction, Coronary artery bypass grafting
study demographics (sample size, publication year, design, and country), patient demographics and comorbidities (age, sex, diabetes, ejection fraction, chronic obstructive pulmonary disease). In the first screening phase, we have excluded 101 papers due to they were irrelevant. The modification of the Newcastle-Ottawa scale is carried out in our meta-analysis with a quality assessment score. The modified Newcastle-Ottawa scale checklist has been summarized in Table 1, and we also define the studies scores higher than 6 as the high-quality study. The quality of all studies has been evaluated by two independent researchers (Zhou; Lin).

**Outcomes**

The primary clinical endpoint was 30-days mortality. The secondarily clinical endpoint was stroke, myocardial infarction and renal failure, atrial fibrillation, renal failure, pulmonary complications, postoperative transfusion, neurological dysfunction and infection. Pulmonary complications were include respiratory failure (pulmonary insufficiency requiring intubation and ventilation for a period of 72 h or more at any time during the postoperative stay) and postoperative pneumonia (positive sputum cultures with subsequent antibiotic treatment, or an infiltrate on postoperative chest x-ray diagnosed as pneumonia or pneumonitis). The period of secondarily clinical outcome were defined as 30 days after surgery.

**Statistical analysis**

The relationship between on-pump and off-pump CABG and clinical outcome was compared directly by pooling data from the included studies using “meta” and “metaphor” packages in R (version 3.5.3; R Project; R Foundation for Statistical Computing, Vienna, Austria) [8]. We pooled the clinical outcome using OR with 95% CI. OR were used as the common measure for dichotomous data follow by the previous study [7] and Cochrane Handbook for Systematic Reviews of Intervention [9]. The random-effects model because variation among studies due to patients undergoing operations in different centers have varying risk profiles and selection criteria for each surgical technique. We evaluated the heterogeneity by focusing on patients with LVD and a
quality score greater than 7 and Heterogeneity was reported as low ($I^2 = 0\text{–}25\%$), moderate ($I^2 = 26\text{–}50\%$), high ($I^2 > 50\%$), consistent with guidelines. Publication bias was assessed visually by funnel plot and quantitatively by the Egger test [10]. We calculated pooled ORs using the Mantel-Haenszel method. A leave-one-out analysis was performed to examine the impact of individual studies on the robustness of the primary and secondary outcomes. Statistical significance was assumed for $P < 0.05$.

### Results

Among the 987 screened articles, article excluded due to screened title(29 studies), abstract(60 studies), key word(12 studies) at first time and full text(25 studies) at second time. a total of 16 studies(32,354 patients; 24,295 case of on-pump CABG and 8269 cases of off-pump CABG) were included (Table 2).

Six of the studies were multicenter. Five studies formed the USA, three from UK and two from Israel, and one each from Canada, Korea, Brazil, China, Switzerland and Japan. All observational studies included were of high quality and low risk of bias. The number of patients in the individual studies ranged from 26 to 20,509 patients in the on-pump CABG group and from 31 to 5158 in the off-pump CABG group. The overall mean age ranged from 65.62 years in the on-pump CABG group and 64.23 in the off-pump CABG group. In the off pump group, the overall percentage of female varied from 12.9\text{–}38\%, whilst in the on pump group the percentage of female ranged from 8 to 36.3%. All patients had low-normal ejection fraction (range from $\leq 20\%$ to $\leq 35\%$).

For short-term outcomes, mortality was reported in 15 studies (31,668 patients) [11\text{–}21] and pulmonary complication in 9 studies (3987 patients) [11, 12, 15, 16, 19, 20, 22, 23], renal failure in 15 studies (31,801 patients) [5, 11\text{–}18, 20\text{–}22, 24], infection in 8 studies (5037 patients) [5, 11, 12, 14, 15, 20, 25], AF in 12 studies (30,789 patients) [12, 14\text{–}20, 22\text{–}25], postoperative transfusion in 4 studies (2565 patients) [20, 21, 24, 25], reoperation for bleeding in 11 studies (5418 patients) [5, 11, 13, 14, 16, 20, 21, 23, 24], MI in 13 studies (31,686 patients) [5, 11\text{–}20, 22, 23, 25] and neurological dysfunction in 7 studies (1536 patients) [12, 14\text{–}20, 22, 23, 25].

#### Primary outcomes

30-day mortality was 3.34% in off-pump group versus 3.53% in on-pump group (OR, 0.84; 95\%CI, 0.73\text{–}0.97; $P = 0.02$) and Leave-one-out analysis supported the robustness of this finding(Figure 2). Funnel plot showed no publication bias (Egger test intercept was $-1.53\text{–}0.12$, $P = 0.12$,Supplementary Figure 1a). However, when excluding the study of Ueki, C. et.al, the off-pump was no longer associated with a significantly lower risk of 30-day mortality. (Supplementary Figure 1b).

### Table 1 Quality assessment of included studies using Newcastle-Ottawa scale

| First author | Year | Selection | Comparability | Outcome | Total |
|--------------|------|-----------|---------------|---------|-------|
| Arom, K.V.   | 2000 | 1 1 0 1   | 1 0           | 1 1 1   | 7     |
| Yokoyama, T. | 2000 | 1 1 0 1   | 1 0           | 1 1 1   | 7     |
| Shennib, H.  | 2002 | 1 1 0 1   | 1 0           | 1 1 1   | 7     |
| Al-Ruzzeh, S.| 2003 | 1 1 0 1   | 1 0           | 1 1 1   | 7     |
| Ascione, R.  | 2003 | 1 1 0 1   | 1 1           | 1 1 1   | 8     |
| Goldstein, D.J. | 2003 | 1 1 0 1   | 1 1           | 1 1 1   | 7     |
| Darwazah, A.K.| 2006 | 1 1 0 1   | 1 1           | 1 1 1   | 8     |
| Sharoni, E.  | 2006 | 1 1 0 1   | 1 1           | 1 1 1   | 7     |
| Filsoufi, F. | 2007 | 1 1 1 1   | 1 0           | 1 1 1   | 8     |
| Youn, Y.N.   | 2007 | 1 1 0 1   | 1 0           | 1 1 1   | 7     |
| Qiu, Z.B.    | 2008 | 1 1 0 1   | 1 0           | 1 1 1   | 8     |
| Attaran, S.  | 2010 | 1 1 0 1   | 1 0           | 1 1 1   | 7     |
| Caputti, G.M.| 2011 | 1 1 0 1   | 1 0           | 1 1 1   | 7     |
| Emmert, M.Y. | 2012 | 1 1 0 1   | 1 0           | 1 1 1   | 7     |
| Keeling, W.B.| 2013 | 1 1 0 1   | 1 0           | 1 1 1   | 7     |
| Ueki, C.     | 2016 | 1 1 0 1   | 1 0           | 1 1 1   | 7     |

S1: Representativeness of the exposed cohort; S2: Selection of the non-exposed cohort; S3: Ascertainment of exposure; S4: Demonstration that outcome of interest was not present at start of study; C1&2: Comparability of cohorts on the basis of the design or analysis; O1: Assessment of outcome; O2: Was follow-up long enough for outcomes to occur; O3: Adequacy of follow-up of cohorts.
| Author          | Year | Arm     | Total patients | Gender, mean (SD) | Smoker | COPD | Hypertension | Diabetes | Dyslipidemia | Renal dysfunction | MI | CVA | TDV | LVEF   |
|-----------------|------|---------|----------------|-------------------|--------|------|-------------|----------|--------------|-------------------|----|-----|-----|--------|
| Arom, K.V.      | 2000 | off-pump | 45             | 70.20 (11.80)     | 16     | 10   | 6           | 30       | 15           | NR                | NR | 4   | NR  | 24.80 ± 5% |
|                 |      | on-pump  | 132            | 66 (11.60)        | 27     | 24   | 17          | 71       | 45           | NR                | NR | 11  | NR  | 26.40 ± 4% |
| Yokoyama, T.    | 2000 | off-pump | 242            | 67 NR             | 68     | NR   | NR          | 34       | NR           | 83                | NR | NR | NR  | ≤25.00% |
|                 |      | on-pump  | 483            | 68 NR             | 68     | NR   | NR          | 44       | NR           | 140               | NR | NR | NR  | ≤25.00% |
| Shennib, H.     | 2002 | off-pump | 31             | 646 (0.9)         | 4      | 9    | 1           | 13       | 13           | 17                | 3  | 25  | 2   | 28.80 ± 6.10% |
|                 |      | on-pump  | 46             | 6450 (9.90)       | 7      | 20   | 7           | 24       | 13           | 20                | 4  | 45  | 4   | 28.40 ± 5.80% |
| Al-Ruzzeh, S.   | 2003 | off-pump | 106            | NR                | 24     | 78   | 7           | 65       | 32           | 73                | 2  | 56  | 15  | 21.60 ± 1.80% |
|                 |      | on-pump  | 199            | NR                | 67     | 153  | 19          | 97       | 61           | 106               | 13 | 127 | 24  | 21.80 ± 1.20% |
| Ascione, R.     | 2003 | off-pump | 74             | 66 NR             | 10     | 61   | NR          | 51       | 23           | 54                | NR | 61  | 7   | ≤30.00% |
|                 |      | on-pump  | 176            | 65                | 14     | 132  | NR          | 94       | 41           | 130               | NR | 139 | 27  | ≤30.00% |
| Darwazah, A.K.  | 2006 | off-pump | 66             | 56.10 (10.80)     | 14     | 43   | 15          | 34       | 30           | 29                | 10 | 44  | NR  | 27.50 ± 5.50% |
|                 |      | on-pump  | 84             | 58.70 (9.40)      | 25     | 44   | 8           | 38       | 44           | 36                | 8  | 42  | NR  | 30.10 ± 4.2% |
| Sharoni, E.     | 2006 | off-pump | 144            | 63 (10.60)        | 40     | 55   | 58          | 109      | 67           | NR                | 19 | 106 | NR  | 28 ± 7% |
|                 |      | on-pump  | 209            | 61.90 (10.90)     | 36     | 73   | 48          | 143      | 80           | NR                | 26 | 162 | NR  | 28 ± 6% |
| Filsoufi, F.    | 2007 | off-pump | 71             | 69 (11)           | 27     | NR   | 8           | 54       | 36           | NR                | 9  | 47  | 9   | ≤3000% |
|                 |      | on-pump  | 424            | 65 (11)           | 117    | NR   | 40          | 327      | 193          | NR                | 33 | 339 | 32  | ≤3000% |
| Youn, Y.N.      | 2007 | off-pump | 100            | 62.90 (8.80)      | 27     | 50   | 3           | NR       | 56           | 46                | 14 | 59  | 12  | ≤35.00% |
|                 |      | on-pump  | 53             | 62.00 (9.20)      | 15     | 20   | 3           | NR       | 26           | 22                | 7  | 27  | 4   | ≤35.00% |
| Qu, Z.B.        | 2008 | off-pump | 84             | NR                | 20     | 62   | 16          | 54       | 27           | 59                | 5  | 45  | 8   | 30.91 ± 1.24% |
|                 |      | on-pump  | 102            | NR                | 37     | 79   | 23          | 53       | 35           | 56                | 10 | 65  | 6   | 30.62 ± 1.58% |
| Attaran, S.     | 2010 | off-pump | 406            | 67                | 60     | 79   | 172         | 251      | 132          | 375               | 51 | 69  | 45  | ≤3000% |
|                 |      | on-pump  | 528            | 66.10            | 70     | 107  | 222         | 286      | 143          | 458               | 51 | 75  | 54  | ≤3000% |
| Capuetti, G.M.  | 2011 | off-pump | 105            | 71 (3)           | 27     | 26   | 14          | 70       | 31           | 40                | 12 | 42  | 4   | ≤2000% |
|                 |      | on-pump  | 112            | 67 (2)           | 23     | 29   | 13          | 59       | 38           | 48                | 10 | 40  | 8   | ≤2000% |
| Emmert, M.Y.    | 2012 | off-pump | 256            | 64 (10)          | 49     | 157  | 13          | 149      | 91           | 167               | 11 | 176 | 6   | ≤3500% |
|                 |      | on-pump  | 222            | 63 (9)           | 34     | 133  | 24          | 112      | 50           | 159               | 10 | 203 | 0   | ≤3500% |
| Keeling, W.B.   | 2013 | off-pump | 5158           | 65 (11.10)       | 1161   | NR   | NR          | 4393     | 2560         | NR                | 277| 3419| 882 | 23% (20–25)% |
|                 |      | on-pump  | 20509          | 64               | 4138   | NR   | NR          | 17,245   | 10,716        | NR                | 923| 13,644| 3287 | 23% (20–25)% |
| Ueki, C.        | 2016 | off-pump | 1053           | 67.40 (10.10)    | 150    | 701  | NR          | 758      | 633          | 571               | 128| 615 | 182 | 27.20 ± 7.90% |
|                 |      | on-pump  | 1134           | 65.70 (10.20)    | 156    | 742  | NR          | 835      | 731          | 669               | 160| 693 | 150 | 26.60 ± 10.40% |

*COPD chronic obstructive pulmonary disease, CVA Cerebrovascular accident, TDV Three diseased vessel, NR not reported*
Secondary outcomes
Off-pump was associated with less stroke (OR, 0.69; 95% CI, 0.55–0.86; P = 0.00), MI (OR, 0.71; 95% CI, 0.53–0.96; P = 0.02), renal failure (OR, 0.71; 95% CI, 0.55–0.93; P = 0.01), the pulmonary complication (OR, 0.68; 95% CI, 0.52–0.90; P = 0.01), infection (OR, 0.67; 95% CI, 0.49–0.91; P = 0.00), postoperative transfusion (OR, 0.25; 95% CI, 0.08–0.84; P = 0.02), reoperation for bleeding (OR, 0.56; 95% CI, 0.41–0.75; P = 0.00) respectively. However, there was no significant difference in terms of AF (OR, 0.95; 95% CI, 0.78–1.41; P = 0.56) and neurological dysfunction (OR, 0.84; 95% CI, 0.49–1.57; P = 0.65) (Figs. 3, 4, 5, 6, 7, 8, 9, 10, 11).
Discussions

This study showed that off-pump CABG can be performed with better operative mortality than on-pump CABG among patients with severe LVD in our meta-analysis of contemporary observational clinical studies involving a large cohort of patients. OPCAB were also demonstrated that the rate of stroke, myocardial infarction, renal failure, pulmonary complication, infection, postoperative transfusion and reoperation for bleeding have better advantage than ONCAB.

The results of the present study are consistent with large individual studies included in the current meta-analysis. Kunadian et al. found that CABG can be performed with acceptable operative mortality and 5-year
actuarial survival in patients with severe LV dysfunction in the meta-analysis [26]. The Japan Adult Cardiovascular Surgery Database registry of 918 patients with low EF (less than 0.30) reported an operative mortality of 3.30% with off-pump CABG than on-pump CABG (6.10%) [20]. Keeling et al. in the series of 25,667 patients demonstrated that off-pump CABG compared with on-pump CABG was associated with superior predicted mortality risk (2.30% vs 2.10%, \(P = 0.0001\)) and Major adverse cardiac events (MACE) (4.40% vs 5.30%, \(P = 0.01\)) including stroke, MI and atrial fibrillation [17]. Likewise, in a series of 217 patients with EF \(\leq 20\%\), Capptti et al. demonstrated the operative mortality of 12.50% in the cardiopulmonary bypass group and 3.80% in the off-pump group [27].

The less release of inflammatory mediators, cardioplegia, hypothermia, well blood supply for the sub-endocardium and minimally invasive procedure without cross-clamping, cardiologic arrest and improve flow in IMA grafts make the off-pump CABG an almost-ideal technique for surgery [28–32]. Compared with off-pump CABG, on-pump CABG also has the additional advantage of complete revascularization, hemodynamic deterioration and repeated surgical interventions [30]. Off-pump CABG was also associated with a significantly lower incidence of renal failure, stroke, myocardial infarction, pulmonary complications, postoperative transfusion, infection in this high-risk cohort. A recent large-scale clinical trial study by Garg demonstrated that off-pump reduced the risk of acute postoperative kidney than on-pump CABG, but no
evidence shows better-preserved kidney function at 1 year follow. Avoidance of transfusion and eliminate extracorporeal circulation is thought to be the main reasons for the lower incidence of renal failure [28, 33, 34]. Numerous studies have reported the association of off-pump CABG with the reduced requirement of transfusion in patients with left ventricular dysfunction [35]. However, No improvement in neurocognitive outcomes after off-pump versus on-pump coronary revascularization [36].

The off-pump CABG involves less hypercoagulable state and thromboembolic events, thus reducing microemboli, activation of the coagulation and inflammatory cascades [37]. Yeatman et al. reported that the patients undergoing either off-pump CABG or on-pump CABG for LVD show that off-pump CABG displayed lower requirements for inotropes, less transfusion requirement, and a slightly shorter hospital stay, but at the price of less complete revascularization [38]. Sawada et al. found that coronary revascularization improves long-term survival and a wide range of viability in 274 patients with ischemic left ventricular dysfunction [39]. Jarral et al. found that the preoperative LVEF had adverse effect on

| Study                | off-pump Events | on-pump Events | off-pump vs on-pump | OR    | 95%−CI          | Weight |
|----------------------|-----------------|----------------|--------------------|-------|-----------------|--------|
| Arom, K.V.2000       | 0               | 132            |                    | 1.52  | [0.20; 11.38]   | 2.7%   |
| Shennib, H.2002      | 2               | 46             |                    | 0.46  | [0.05; 4.21]    | 2.3%   |
| Al–Ruzzeh, S.2003    | 1               | 199            |                    | 1.02  | [0.26; 4.06]    | 5.7%   |
| Ascione, R.2003      | 3               | 176            |                    | 3.33  | [0.13; 82.72]   | 1.1%   |
| Goldstein, D.J.2003  | 1               | 0              |                    | 2.65  | [0.47; 14.91]   | 3.7%   |
| Darwazah, A.K.2006   | 4               | 84             |                    | 0.29  | [0.01; 6.03]    | 1.2%   |
| Sharoni, E.2006      | 0               | 209            |                    | 0.45  | [0.03; 8.08]    | 1.4%   |
| Filsoufi, F.2007     | 0               | 424            |                    | 1.34  | [0.25; 7.16]    | 3.9%   |
| Youn, Y.N.2007       | 5               | 53             |                    | 7.77  | [0.92; 65.87]   | 2.4%   |
| Qiu, Z.B.2008        | 6               | 102            |                    | 0.51  | [0.22; 1.17]    | 14.7%  |
| Attaran, S.2010      | 8               | 528            |                    | 1.44  | [0.31; 6.59]    | 4.7%   |
| Caputti, G.M.2011    | 4               | 112            |                    | 0.34  | [0.10; 1.09]    | 7.8%   |
| Emmert, M.Y.,2012    | 4               | 222            |                    | 0.59  | [0.38; 0.93]    | 39.4%  |
| Keeling, W.B.2013    | 22              | 20509          |                    | 0.92  | [0.31; 2.75]    | 8.9%   |
| Ueki, C.2016         | 6               | 1134           |                    | 0.74  | [0.53; 1.04]    | 100.0% |

Random effects model

Heterogeneity: $I^2 = 5\%$, $\tau^2 = 0.0229$, $p = 0.40$

Fig. 8 Forest plot for MI

| Study                | off-pump Events | on-pump Events | off-pump vs on-pump | OR    | 95%−CI          | Weight |
|----------------------|-----------------|----------------|--------------------|-------|-----------------|--------|
| Shennib, H.2002      | 2               | 46             |                    | 1.39  | [0.20; 9.59]    | 9.2%   |
| Al–Ruzzeh, S.2003    | 4               | 106            |                    | 0.28  | [0.01; 6.09]    | 3.6%   |
| Ascione, R.2003      | 3               | 199            |                    | 0.83  | [0.25; 2.75]    | 23.6%  |
| Goldstein, D.J.2003  | 1               | 4              |                    | 1.20  | [0.29; 4.92]    | 17.1%  |
| Emmert, M.Y.,2012    | 9               | 222            |                    | 0.27  | [0.03; 2.44]    | 7.0%   |
|                      | 256             | 8              |                    | 0.97  | [0.37; 2.57]    | 36.3%  |

Random effects model

Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.91$

Fig. 9 Forest plot for neurology complications
long-term survival of patients with LVD and the long-term survival of patients with severe LVD was significantly lower than those with mild to moderate LVD [40]. But Reid et al. demonstrated that the clinical outcome is improved by surgical revascularization can reduce organ dysfunction which also can improve survival [41].

Many preoperative factors were found to be associated with mortality in CABG with LVD including female sex, increasing older age, diabetes, and peripheral vascular disease as predictors [42, 43]. Margo et al. found that the age (>70 years) and female influences on the needs, concerns, and strategies of CABG caregivers. The effect of CABG on all-cause mortality tended to diminish with increasing age through a more significant burden of co-morbidities, which in turn lead to a higher risk of postoperative complications and non-cardiovascular deaths [43]. Both short-and long-term cardiac outcomes of odd-pump CABG are not influenced by age at the operation which prevents the potential complications that can occur in patients undergoing CABG with CPB [44]. The surgeon experience also the essential factors for the

| Study               | Events | Total | Events | Total |
|---------------------|--------|-------|--------|-------|
| Arom, K.V.2000      | 0      | 45    | 0      | 132   |
| Al–Ruzzeh, S.2003   | 9      | 106   | 24     | 199   |
| Ascione, R.2003     | 5      | 74    | 20     | 176   |
| Darwazah, A.K.2006  | 4      | 66    | 6      | 84    |
| Sharoni, E.2006     | 1      | 144   | 2      | 209   |
| Filsoufi, F.2007    | 6      | 71    | 16     | 424   |
| Qiu, Z.B.2008       | 7      | 84    | 8      | 102   |
| Attaran, S.2010     | 11     | 406   | 30     | 528   |
| Ueki, C.2016        | 20     | 1053  | 39     | 1134  |

Random effects model | 2049 | 2988 |

Heterogeneity: $I^2 = 22\%$, $τ^2 = 0.0607$, $p = 0.25$

$0.72 \ [0.50; \ 1.04] \ 100.0\%$

Fig. 10 Forest plot for reoperation for bleeding

| Study               | Events | Total | Events | Total |
|---------------------|--------|-------|--------|-------|
| Arom, K.V.2000      | 0      | 45    | 0      | 132   |
| Shennib, H.2002     | 9      | 31    | 5      | 46    |
| Ascione, R.2003     | 15     | 74    | 37     | 176   |
| Goldstein, D.J.2003 | 20     | 100   | 35     | 110   |
| Darwazah, A.K.2006  | 4      | 66    | 4      | 84    |
| Sharoni, E.2006     | 4      | 144   | 2      | 209   |
| Youn, Y.N.2007      | 14     | 100   | 12     | 53    |
| Qiu, Z.B.2008       | 24     | 84    | 21     | 102   |
| Attaran, S.2010     | 116    | 406   | 156    | 528   |
| Caputti, G.M.2011   | 10     | 105   | 13     | 112   |
| Emmert, M.Y.2012    | 24     | 256   | 14     | 222   |
| Keeling, W.B.2013   | 1001   | 5158  | 4576   | 20509 |
| Ueki, C.2016        | 135    | 1053  | 143    | 1134  |

Random effects model | 7622 | 23417 |

Heterogeneity: $I^2 = 40\%$, $τ^2 = 0.0279$, $p = 0.07$

$0.94 \ [0.79; \ 1.13] \ 100.0\%$

Fig. 11 Forest plot for postoperative transfusion
clinical outcome of CABG which improved by surgical technique, surgeon volume, and hospital volume, changed surgical training [45–48].

Limitations
There are many limitations should be acknowledged. Firstly, the number of patients, the inclusion and the exclusion criteria, the type of surgery, the indication for CABG, methods for the assessment of LV function and the definition of the severe LVD varied across the studies, and the EF has represented a systolic function which cannot be demonstrated left ventricular dimension and diastolic function. Secondly, the surgeon’s volume index and institutional volume index also were not significantly associated with the clinical outcome because the learning curve of off-pump CABG is longer than on-pump CABG. Finally, the present study remains subject to the inherent caveats of a meta-analysis including publication bias, however, in-depth statistical analysis was performed to account for these limitations. In future, the more RCT studies need to studies the clinical outcome of OPCAB and ONCAB.

Conclusions
The published evidence on the clinical effect of the use the off-pump CABG for LVD is mainly derived single-center observational studies from the institutions. The key finding is that the use of off-pump CABG is associated with a reduction in mortality and this finding also provide better implications for clinicians and policymakers.

Supplementary information
Supplementary information accompanies this paper at https://doi.org/10.1186/s13019-020-01115-0.

Additional file 1. Search strategy.
Additional file 2: Figure S1. a-1b 30-day mortality: (a) Funnel plot with Egger test results and (b) Leave-one-out analysis.

Abbreviations
LVD: Left ventricular dysfunction; CABG: Coronary artery bypass grafting; CNS: Central nervous system complications; ICU LOS: The length of stay of an intensive care unit; CPB: Cardiopulmonary bypass; MED: Medical therapy; AKI: Acute kidney disease; CKD: Chronic kidney disease

Acknowledgements
Not applicable.

Patient and public involvement
This is no patient and public involvement.

Authors’ contributions
Conceived and designed the experiments: ZYG MX CLS ZZ FW. Performed the experiments: ZYG XQG YQL. Analyzed the data: ZYG XQG KYG YQL. Contributed reagents/materials/analysis tools: ZYG XQG KYG YQL WJZ MX CLS. Wrote the paper: ZYG XQG KYG YQL WJZ MX CLS. Contributed reagents/materials/analysis tools: ZYG XQG KYG YQL WJZ MX CLS.

Funding
This work was partly supported by the National Natural Science Foundation of China (Grant No. 11902149). This work is also sponsored by China Postdoctoral Science Foundation Grant (Grant No. 2018 M640030) and Key clinical project of Peking University Third Hospital(7Y5510-04).

Availability of data and materials
Not applicable.

Ethics approval and consent to participate
As a meta-analysis, no patients involved in the recruitment to and conduct of the study and there also no results be disseminated to study participants. The inclusion criteria and exclusion criteria were used to screen inclusion studies, and leave-out tests were used to analyze the impact of each study on the overall structure.

Consent for publication
Not applicable.

Competing interests
There is no found and interest in the papers.

Author details
1Department of Cardiology surgery, Peking University Third Hospital, 49 North Garden Rd., Haidian District, Beijing 100191, China. 2Peking University, Beijing 100871, China. 3Beijing University of Technology, Beijing 100124, China. 4Department of Cardiology, Peking University Third Hospital, NHC Key Laboratory of Cardiovascular Molecular Biology and Regulatory Peptides, Beijing 100191, China. 5Shanghai East Hospital, Tongji University, 150 Jimo Rd., Pudong District, Shanghai 100124, China. 6Department of Orthopedics, Peking University Third Hospital, 49 North Garden Rd., Haidian District, Beijing 100191, China.

Received: 19 December 2019 Accepted: 27 April 2020
Published online: 11 May 2020

References
1. Kowalewski M, et al. Off-pump coronary artery bypass grafting improves short-term outcomes in high-risk patients compared with on-pump coronary artery bypass grafting: Meta-analysis. J Thorac Cardiovasc Surg. 2016;151(1):50–7.
2. Smart NA, Dieberg G, King N. Long-term outcomes of on-versus off-pump coronary artery bypass grafting. J Am Coll Cardiol. 2018;71(9):983–91.
3. Topkara VK, et al. Coronary artery bypass grafting in patients with low ejection fraction. Circulation. 2005;112(9 Suppl):I44–50.
4. Luchi RJ, Scott SM, Deupree RH. Comparison of medical and surgical treatment for unstable angina pectoris. Results of a veterans administration cooperative study. N Engl J Med. 1987;316(16):977–84.
5. Filosou F, et al. Results and predictors of early and late outcome of coronary artery bypass grafting in patients with severely depressed left ventricular function. Ann Thorac Surg. 2007;84(3):808–16.
6. Ferguson TB Jr, et al. A decade of change–risk profiles and outcomes for isolated coronary artery bypass grafting procedures, 1990–1999: a report from the STS National Database Committee and the Duke Clinical Research Institute. Society of Thoracic Surgeons. Ann Thorac Surg. 2002;73(2):480–9 discussion 489-90.
7. Jarral OA, Saso S, Athanasiou T. Off-pump coronary artery bypass in patients with left ventricular dysfunction: a meta-analysis. Ann Thorac Surg. 2011;92(3):1686–94.
8. Viechtbauer W. Conducting Meta-analyses in R with the metafor package. J Stat Softw. 2010;36(3):1–48.
9. Higgins JP, Green S. Cochrane handbook for systematic reviews of interventions: Cochrane book series; 2008.
10. Higgins JP, et al. Measuring inconsistency in meta-analyses. BMJ. 2003;327(7414):557–60.
11. Al-Ruzzeh S, et al. Is the use of cardiopulmonary bypass for multivessel coronary artery bypass surgery an independent predictor of operative mortality in patients with ischemic left ventricular dysfunction? Ann Thorac Surg. 2003;76(2):444–51 discussion 451-2.
12. Arom KV, et al. Is low ejection fraction safe for off-pump coronary bypass operation? Ann Thorac Surg. 2000;70(3):1021–5.
