Review Article

Global Spine Journal
2021, Vol. 11(7) 1121-1133
© The Author(s) 2020
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/2192568220959265
journals.sagepub.com/home/gsj

Comparison of the Safety of Outpatient Cervical Disc Replacement With Inpatient Cervical Disc Replacement: A Systematic Review and Meta-Analysis

Xiaofei Wang, MD[1]*, Yang Meng, MD[1]*, Hao Liu, MD, PhD[1], Ying Hong, MD[1,2], Beiyu Wang, MD[1], Chen Ding, MD[1], and Yi Yang, MD[1]

Abstract

Study Design: A systematic review and meta-analysis.

Objectives: Outpatient cervical disc replacement (CDR) has been performed with an increasing trend in recent years. However, the safety profile surrounding outpatient CDR remains insufficient. The present study systematically reviewed the current studies about outpatient CDR and performed a meta-analysis to evaluate the current evidence on the safety of outpatient CDR as a comparison with the inpatient CDR.

Methods: We searched the PubMed, Embase, Web of Science, and Cochrane Library databases comprehensively up to April 2020. Patient demographic data, overall complication, readmission, returning to the operation room, operating time were analyzed with the Stata 14 software and R 3.4.4 software.

Results: Nine retrospective studies were included. Patients underwent outpatient CDR were significantly younger (mean difference [MD] = −1.97; 95% CI −3.80 to −0.15; $P = .034$) and had lower prevalence of hypertension (OR = 0.68; 95% CI 0.53-0.87; $P = .002$) compared with inpatient CDR. The pooled prevalence of overall complication was 0.51% (95% CI 0.10% to 1.13%) for outpatient CDR. Outpatient CDR had a 59% reduction in risk of developing complications (OR = 0.41; 95% CI 0.18-0.95; $P = .037$). Outpatient CDR showed significantly shorter operating time (MD = −18.37; 95% CI −25.96 to −10.77; $P < .001$). The readmission and reoperation rate were similar between the 2 groups.

Conclusions: There is a lack of prospective studies on the safety of outpatient CDR. However, current evidence shows outpatient CDR can be safely performed under careful patient selection. High-quality, large prospective studies are needed to demonstrate the generalizability of this study.

Keywords
cervical disc replacement, outpatients, ambulatory, safety, complication, meta-analysis

Introduction

Cervical disc replacement (CDR) is a commonly used procedure for the treatment of cervical degenerative disc disease (CDDD). With the aging of population and change of lifestyle, the number of CDR performed annually is increasing, with an average of 17% increment per year.[1] Compared with the traditional anterior cervical discectomy and fusion (ACDF), CDR preserves the motion function at pathological levels and restores the biomechanical properties of the intact cervical spine to the most extent. Biomechanical studies have shown

[1] West China Hospital, Sichuan University, Chengdu, China
[2] West China School of Nursing, Sichuan University, Chengdu, China
* Xiaofei Wang and Yang Meng contributed equally to this work and should be considered co–first authors.

Corresponding Authors:
Hao Liu, Department of Orthopedic Surgery, West China Hospital, Sichuan University, No. 37, Guo Xue Xiang, Chengdu, Sichuan Province, China.
Email: dr.liuhao6304@yahoo.com

Ying Hong, West China School of Nursing, Department of Anesthesia and Operation Center, West China Hospital, Sichuan University, No. 37, Guo Xue Xiang, Chengdu, Sichuan Province, China.
Email: hongying518@163.com

Creative Commons Non Commercial No Derivs CC BY-NC-ND: This article is distributed under the terms of the Creative Commons Attribution-Non Commercial-NoDerivs 4.0 License (https://creativecommons.org/licenses/by-nc-nd/4.0/) which permits non-commercial use, reproduction and distribution of the work as published without adaptation or alteration, without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (https://us.sagepub.com/en-us/nam/open-access-at-sage).

that the intervertebral disc pressure and segmental motion at adjacent levels of CDR are comparable with those of the intact cervical spine.[2-4] Randomized controlled studies (RCTs) also demonstrated that CDR could prevent adjacent segment degeneration (ASD) compared with ACDF.[5-7] Therefore, CDR has become an important option for the treatment of CDDD.

Although CDR is efficient in treating cervical degenerative disc disease, the costs of this procedure are very high. Kumar et al[8] used the MarketScan database and found that the mean cost of CDR was $28 664. Jain et al[1] reviewed the PearlDiver Patient Record Database and found that the mean cost for single-level CDR was about $35 000 and for multilevel CDR was about $62 000. Their evidence suggests that CDR brings a great economic burden to patients and the health care system.

Recently, with the advances in anesthesiology and the development of Enhanced Recovery After Surgery (ERAS), many surgeries have been transited to outpatient procedures. The outpatient surgery does not need an overnight stay in the hospital, this not only increases patient satisfaction[9,10] but also reduces hospital-related costs. In fact, several studies reported that compared with inpatient procedures, outpatient CDR reduced the mean cost by 42% to 84%.[11,12] Therefore, outpatient CDR could be a useful way to reduce costs.

Outpatient CDR has been performed with an increasing trend in recent years.[1,13] Several studies have reported the efficacy and safety of outpatient CDR.[11-19] However, the generalizability of these studies is limited by the small sample size and lack of control groups. Therefore, the safety profile surrounding outpatient CDR remains insufficient.

In this study, we systematically reviewed the current studies about outpatient CDR and performed a meta-analysis to evaluate the current evidence on the safety of outpatient CDR as a comparison with the inpatient CDR.

Methods

This study was conducted following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines. The protocol of this study has been registered on the Open Science Framework website (10.17 605/OSF.IO/3597Z).

Search Strategy

We searched the following database from inception to April 15, 2020: PubMed, Embase, Web of Science, and Cochrane Library. The following search keywords were used in all databases: "total disc replacement," "outpatients," "ambulatory." The search strategy uploaded onto the Open Science Framework website (osf.io/szuy9/). Articles wrote in English were included. The reference lists of the eligible studies were reviewed to identify the potentially relevant studies.

Eligibility Criteria

The inclusion criteria of this study were listed as follows: (1) Type of studies: Considering that the majority of published studies on this topic are retrospective studies, both prospective studies and retrospective cohort studies were included. (2) Type of interventions: Studies reporting the outcomes of outpatient CDR were included. (3) Types of outcomes: Studies reporting the incidence of overall complication, readmission, and reoperation after outpatient CDR were included. Two authors (XW and HW) independently included the eligible studies, and no disagreement was noted in this process between the 2 authors.

Data Extraction

The following data was extracted: (1) Study information, including author name, year of publication, conflict of interest, funds, type of study, sample size, type of device, definition of outpatient surgery, and follow-up time period. (2) Patient information, including age, gender, body mass index (BMI), and comorbidities. (3) Surgical information, including operating time, surgical level, and length of stay. (4) All reported outcomes, including complications found in outpatient CDR, readmission, and reoperation. Data extraction was performed by 2 authors (XW and HW). Any disagreement between the 2 authors was solved by consulting a senior author (HL).

Quality Assessment

The Newcastle-Ottawa scale (NOS) was used to evaluate the quality of eligible studies. Two authors (XW and HW) performed the assessment independently according to previous research. Any disagreement between the 2 authors was solved by consulting a senior author (HL).

Statistical Analysis

This meta-analysis was conducted using Stata (V.14, StataCorp) software, and R (V.3.4.4, R Foundation for Statistical Computing). Mean differences (MDs) with 95% confidence intervals (CIs) were used to display continuous variables. Odds ratio (OR) with 95% CI were used for the analysis of categorical variables. The incidence of overall complication of outpatient CDR was pooled and displayed with 95% CI. $P < .05$ was considered to be statistically different. The heterogeneity among included studies was assessed using the I^2 test. An I^2 value >50% was considered as high heterogeneity, and data was analyzed using the random-effects model. Otherwise, data was analyzed using the fixed-effects model. Subgroup analysis was performed according to the surgical level. The funnel plot, Begg's test, and Egger's regression test were used to examine the publication bias.

Results

Literature Search Results

Nine retrospective cohort studies matched the eligibility criteria of our study (Figure 1). Among them, 1 study was published in 2010 and the rest of the studies were published

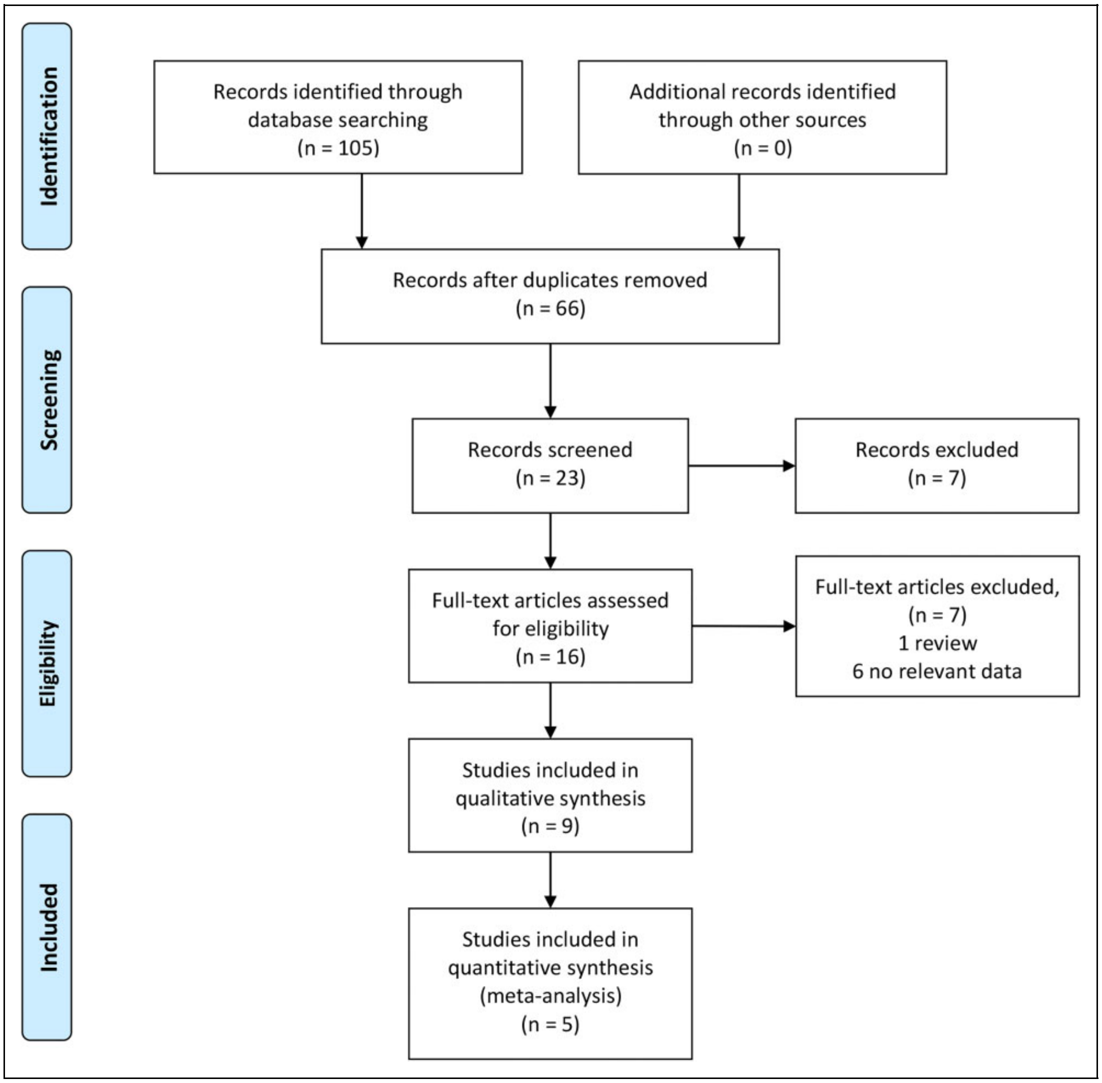

Figure 1. PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) flowchart.

between 2017 and 2020. Five studies compared the safety of outpatient CDR with inpatient CDR, 1 study compared the outpatient CDR with outpatient ACDF, while 3 studies only reported outcomes of outpatient CDR. The basic characteristics of these studies are summarized in Tables 1 and 2. Bovonratwet el al[15] and Segal et al[14] used the same database (National Surgical Quality Improvement Program [NSQIP]) and may have overlapping data sets. However, the study by Segal et al[14] had a larger sample size; therefore, it was included in the quantitative analysis.

Study Quality Assessment

The results of the quality assessment are listed in Table 3. For studies that directly compared outcomes of outpatient CDR with inpatient CDR, 3 of them scored 9 points, and 2 of them scored 7 points. The other 4 studies that reported outcomes of outpatient CDR scored 6 points. All studies were of good quality.

Demographic Data of Included Studies

The demographic data of included studies is summarized in Table 2 and Figure 2. Outpatients and inpatients had a similar sex distribution (OR = 1.04, 95% CI 0.90-1.20; $Z = 0.55$, $P = .582$), body mass index (BMI) (MD = −0.71, 95% CI −1.91 to 0.50; $Z = 1.16$, $P = .245$), smoking status (OR = 1.02, 95% CI 0.91-1.28; $Z = 0.14$, $P = .888$), and the prevalence of diabetes (OR = 0.65, 95% CI 0.42-1.02; $Z = 1.89$, $P = .059$) and overweight (OR = 0.93, 95% CI 0.76-1.15; $Z = 0.66$, $P = .508$). However, outpatients had significantly younger age (MD = −1.97; 95% CI −3.80 to −0.15; $Z = 2.12$; $P = .034$) and lower prevalence of hypertension (OR = 0.68; 95% CI 0.53-0.87; $Z = 3.09$; $P = .002$) compared with inpatients.

Overall Complication

Eight studies reported overall complication rates for outpatient CDR, ranging from 0% to 3.64%. The safety profile is summarized in Table 1. Four studies reported overall complication rates

Table 1. Summary of the Safety Profile of Outpatient Cervical Disc Replacement.

Study	Data source (year)	Surgical type	Number of cases	Complication rate	Follow-up time	Complications found in outpatient CDR
Bovonratwet[15] (2019)	NSQIP (2005-2016)	One-level CDR	1492 patients; 373 outpatients, 1119 inpatients	Outpatients 0.8% Inpatients 1.97%	30 days	Pulmonary complication, herniation of cervical intervertebral disc
Purger[12] (2019)	HCUP, SID, SASD, SEDD (2009-2011)	NR	2159 patients; 370 outpatients, 1789 inpatients	NR	30 days	Infection, hematoma, surgical site complication, complications from procedures
Segal[14] (2018)	NSQIP (2009-2017)	One-level CDR	1506 patients; 525 outpatients, 981 inpatients	Outpatients 0.76% Inpatients 1.73%	30 dasy	Pneumonia, unplanned intubation, postoperative sepsis, Clavien-Dindo IV complication
Hill[13] (2018)	NSQIP (2014-2016)	Two-level CDR	226 patients; 76 outpatients, 150 inpatients	Outpatients 0 Inpatients 1.33%	30 days	No complication or readmission
Gornet[16] (2018)	Local patient (2006-2015)	One- or 2-level CDR	558 patients; 493 outpatients, 65 inpatients	Outpatients 1.62% Inpatients 4.62%	90 days	Wound dehiscence, other not known
Cuellar[19] (2020)	Local patient (NR)	One- or multilevel CDR	147 outpatients	Outpatients 1.36%	90 days	Intractable nausea and vomiting, superficial surgical site infection
Chin[17] (2017)	Local patient (2012-2013)	One-level CDR	55 outpatients	Outpatients 3.64%	2 years	Dysphagia
Chin[18] (2017)	Local patient (NR)	Two-level hybrid surgery	15 outpatients	Outpatients 0	1 year	No complication
Wohns[11] (2010)	Local patient (2009-2010)	One-level CDR	26 outpatients	Outpatients 0	21 day	No major complication

Abbreviations: NR, not reported; CDR, cervical disc replacement; NSQIP, National Surgical Quality Improvement Program; HCUP, Healthcare Cost and Utilization Project; SID, Services' Agency for Healthcare Research and Quality State Inpatient Databases; SASD, State Ambulatory Surgery and Services Databases; SEDD, State Emergency Department Databases.

Table 2. Basic Characteristics of Included Studies.

Study	Age, years (mean $\pm$ SD)	BMI, kg/m^2 (mean $\pm$ SD)	Gender (male/female)	Comorbidities	Definition of outpatient surgery	Type of artificial cervical disc	Conflict of interest and funding
Bovonratwet[15] (2019)	Outpatient 44.1, Inpatient 44.4	Outpatient 28.9, Inpatient 28.6	Outpatient 217/156, Inpatient 622/497	Similar in comorbidities (diabetes mellitus, hypertension, dyspnea, etc)	Discharged on the same day of surgery	NR	Student research fellowship at Yale University funds
Purger[12] (2019)	Outpatient 42.2 $\pm$ 8.9, Inpatient 46.2 $\pm$ 10.1; $P < .0001$	NR	Outpatient 189/181, Inpatient 835/954	Significant more comorbidities in inpatients (no details)	CDR performed in ASC	NR	No funds or conflict of interest
Segal[14] (2018)	Outpatient 44.4 $\pm$ 9.2, Inpatient 45.5 $\pm$ 10.2	Outpatient 29.0 $\pm$ 6.13, Inpatient 29.1 $\pm$ 6.4	Outpatient 281/244, Inpatient 544/437	Similar in comorbidities (diabetes mellitus, hypertension, dyspnea, etc)	NR	NR	No funds or conflict of interest
Hill[13] (2018)	Outpatient 46.72 $\pm$ 8.62, Inpatient 47.44 $\pm$ 10.5	Outpatient 29.03 $\pm$ 5.55, Inpatient 31.41 $\pm$ 6.58	Outpatient 49/27, Inpatient 84/66	Significant more overweight ($P = .037$) and diabetes requiring insulin ($P = .042$) in inpatients, similar in other comorbidities (hypertension, dyspnea, COPD, etc)	NR	NR	Authors received consulting fees from companies
Gornet[16] (2018)	Outpatient 43.95 $\pm$ 8.87, Inpatient 45.5 $\pm$ 8.6	Outpatient 27.75 $\pm$ 5.12, Inpatient 27.9 $\pm$ 4.5	Outpatient 257/236, Inpatient 38/27	Similar in comorbidities (overweight)	CDR performed in ASC; or patients with 1 night or less stay in a hospital-administrated facility	Mobi-C	Companies sponsored the study in ASC
Cuellar[19] (2020)	Outpatient 50 $\pm$ 10	Outpatient 26.8 $\pm$ 4.6	Outpatient 76/71	Minimal comorbidities (no details)	CDR performed in ASC	Prodisc-C Prestige-LP	No funds or conflict of interest
Chin[17] (2017)	Outpatient 42.4 $\pm$ 1.4	Outpatient 26.2 $\pm$ 1.0	Outpatient 33/22	NR	Discharged within 2-4 hours of completing surgery after detailed assessment	Prodisc-C	No funds or conflict of interest
Chin[18] (2017)	Outpatient 45.13 $\pm$ 1.9	Outpatient 28.1 $\pm$ 8.5	Outpatient 10/5	NR	NR	Prodisc-C	The author receives other benefits from companies
Wohns[11] (2010)	Outpatient 46	NR	Outpatient 12/14	No comorbidities	CDR performed in ASC or in hospital-based outpatient surgery center	Prodisc-C	NR

Abbreviations: NR, not reported; CDR, cervical disc replacement; ASC, ambulatory surgery center.

Table 3. Newcastle-Ottawa Scale Assessment of Included Studies.

	Bovonratwet[15] (2019)	Purger[12] (2019)	Segal[14] (2018)	Hill[13] (2018)	Gornet[16] (2018)	Cuellar[19] (2020)	Chin[17] (2017)	Chin[18] (2017)	Wohns[11] (2010)
Selection									
Representativeness of exposed cohort	1	1	1	1	1	1	1	1	1
Selection of nonexposed cohort	1	1	1	1	1	—	—	—	—
Ascertainment of exposure	1	1	1	1	1	1	1	1	1
Demonstration that outcome of interest was not present at start of study	1	1	1	1	1	1	1	1	1
Comparability									
Study controlled for age or gender	1	0	1	0	1	—	—	—	—
Study controlled for any additional factor	1	0	1	0	1	—	—	—	—
Outcome									
Assessment of outcome	1	1	1	1	1	1	1	1	1
Follow-up long enough for outcomes to occur	1	1	1	1	1	1	1	1	1
Adequacy of follow-up of cohort	1	1	1	1	1	1	1	1	1
Total	9	7	9	7	9	6	6	6	6

for inpatient CDR, ranging from 1.33% to 4.62%. The pooled prevalence of overall complication was 0.51% (95% CI 0.10% to 1.13%) when applying the fixed-effects model (Figure 3A). Subgroup analyses were performed based on levels of operation using the fixed-effects model. One-level outpatient CDR showed a lower complication rate (0.37%; 95% CI 0.01% to 1.04%) than multilevel outpatient CDR (1.15%; 95% CI 0.14% to 2.76%). There were no deaths after outpatient CDR in included studies.

Compared with inpatient CDR, patients underwent outpatient CDR had a 59% reduction in risk of developing complications (OR = 0.41; 95% CI 0.18-0.95; $Z = 2.09$; $P = .037$) without heterogeneity ($I^2 = 0$), as showed in Figure 3B.

The included studies reported no deaths during their follow-up period. The detailed complications for outpatient CDR are listed as follows. Bovonratwet et al.[15] reported that one patient occurred pulmonary complications (on ventilator >48 hours, unplanned intubation, or pneumonia) during the 30-day postoperative period after discharge. Segal et al[14] reported 4 patients with postoperative complications, including 1 Clavien-Dindo IV complication, 1 pneumonia, 1 unplanned intubation, and 1 sepsis. Hematoma was reported by Purger et al[12] with an incidence of 0.27%. Purger et al[12] and Cuellar et al[19] reported 1 case of surgical site infection separately. Cuellar et al[19] also reported 1 case of intractable nausea. Gornet et al[16] reported 8 adverse events, but only wound dehiscence was shown in their article. Dysphagia was reported by Chin et al.[17]

Readmission

Three studies reported the incidence of readmission within 30 days after outpatient CDR compared with inpatient procedure (Figure 4). Patients had a 47% reduction in risk of returning to hospital after surgery if they underwent outpatient CDR (OR = 0.53; 95% CI 0.25-1.11; $Z = 1.68$; $P = .094$). The result showed no heterogeneity ($I^2 = 0$). Although the result favored outpatient CDR, it was not highly significant.

The reasons for readmission of outpatient CDR are listed as follows. Bovonratwet et al[15] reported 2 readmissions of outpatient CDR, 1 with cervical disc displacement (International Classification of Diseases, Ninth Revision [ICD-9]: 722.0), the other with radiculopathy of the cervical region (ICD-9: 723.4). Purger et al[12] reported 19 times of emergency department visits within 30 days after surgery; reasons included chest pain, nausea/vomiting, limb pain, mental disorder, spasm of muscle, headache, and other symptoms involving head and neck. Among them, 2 patients underwent readmission for infection, hematoma, or surgical site complications. The other 2 patients were readmitted for depressive or other reasons. Cuellar et al[19] reported 2 unplanned readmissions for intractable nausea and wound infection.

Return to the Operation Room

Four studies reported the incidence of returning to the operation room within 30 to 90 days after surgery (Figure 5). Patients had a 51% reduction in risk of returning to operation room if they underwent outpatient procedure (OR = 0.49; 95% CI 0.16-1.49; $Z = 1.25$; $P = .210$). However, this result was not statistically significant. There was no heterogeneity among included studies ($I^2 = 0$).

The reasons for return to the operation room of outpatient CDR are listed as follows. Bovonratwet et al[15] reported 1 patient who underwent secondary surgery due to cervical disc displacement (ICD-9: 722.0). Gornet et al[16] reported 3 patients who underwent additional operation of the cervical spine during the 90-day period postoperation.

Operating Time

Three studies reported the operating time of inpatient and outpatient CDR (Figure 6). Compared with the inpatient group, the outpatient group had a significantly shorter operating time

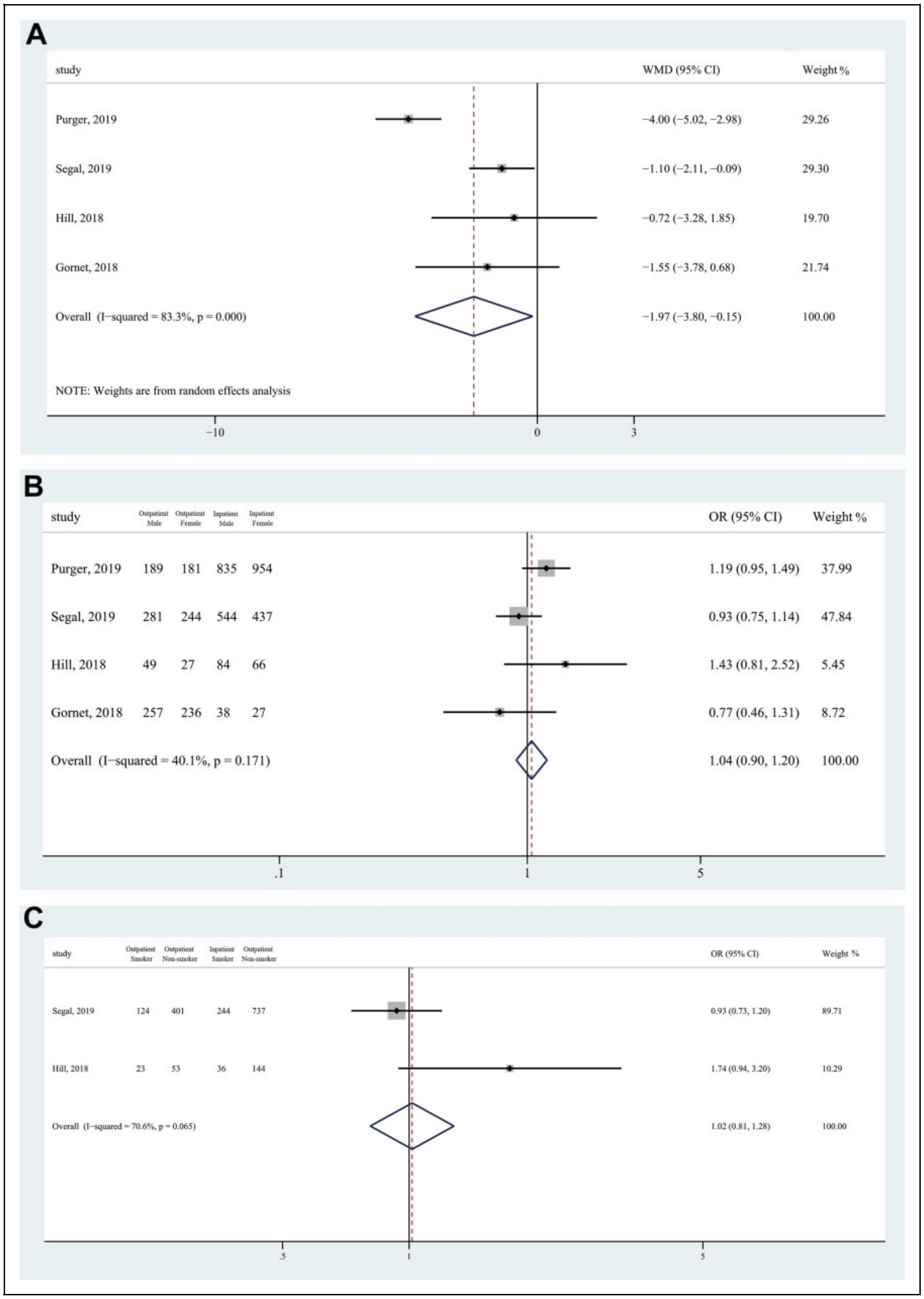

Figure 2. Forest plots of patients' demographic data among included studies. (a) Age, (b) gender, (c) smoking status, (d) body mass index, (e) overweight, (f) hypertension, and (g) diabetes.

(MD = −18.37; 95% CI −25.96 to −10.77; $Z = 4.74$; $P < .001$) with median heterogeneity ($I^2 = 35.6\%$).

Cost for Outpatient CDR

Two studies reported the cost between the outpatient group and the inpatient group.[11,12] Both studies found the average cost for outpatient CDR was lower compared with inpatient procedure (Table 4). Purger et al[12] calculated the 90-day total cost and actual cost. The outpatient group reduced the total cost by 42.0% ($46 404.03 vs $80 055, $P < .0001$) and reduced the actual cost by 35.1% ($11 059 vs $17 033, $P < .001$) compared with the inpatient group. Wohns et al[11] calculated the total cost for surgeries, which was defined as the billed charges for the technical component, implant, and professional fee. They found the outpatient CDR reduced the total cost by 83.6%

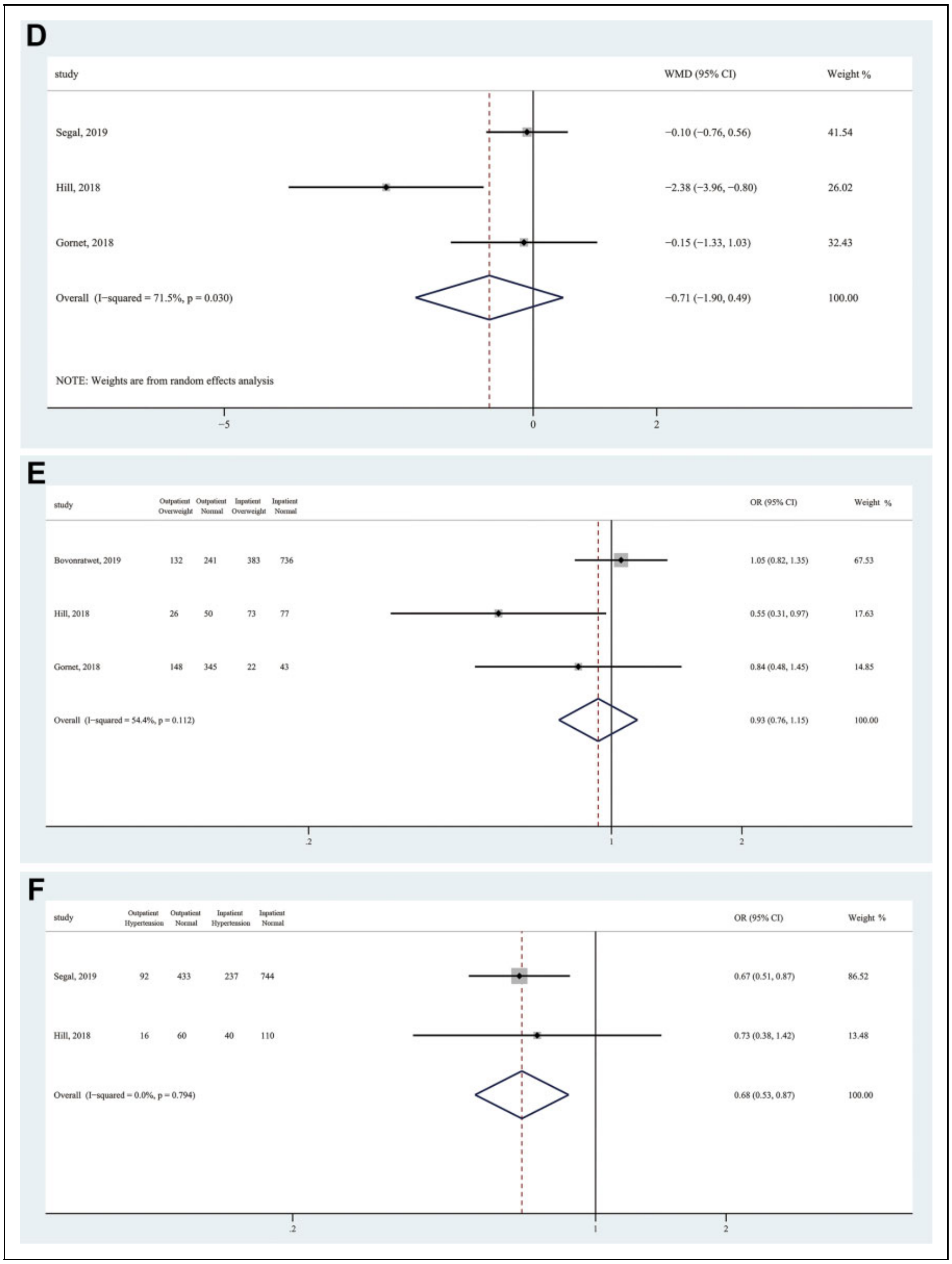

Figure 2. (continued).

compared with inpatient CDR ($11 144.83 vs $68 000, *P* value unknown) and by 62.0% compared with outpatient ACDF ($11 144.83 vs $29 313.43, *P* value unknown). However, it should be noted that there is a lack of high-quality studies regarding the cost-effectiveness of outpatient CDR.

Publication Bias

The funnel plot was graphed to evaluate the publication bias for the overall complication rate (Figure 7). The Begg's test ($P = .462$) and Egger's test ($P = .593$) showed there was no asymmetry in the funnel plot. Although these results did not reveal publication bias, the evaluating ability declined because of a lack of enough publications.

Discussion

The number of surgeries performed in outpatient centers has dramatically increased from 3.7 million in 1981 to over 54 million annually nowadays.[20,21] The transition of inpatient surgeries to the outpatient setting has been considered as a cost reduction strategy. Spine surgery especially represents a huge

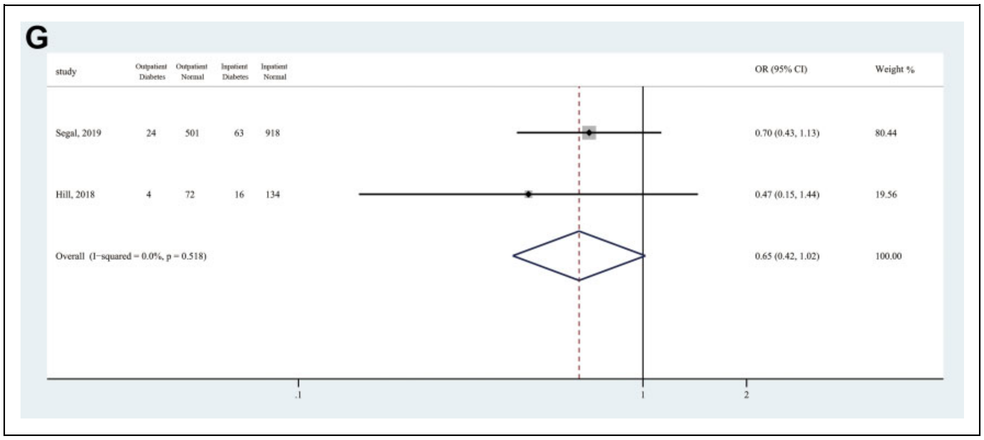

Figure 2. (continued).

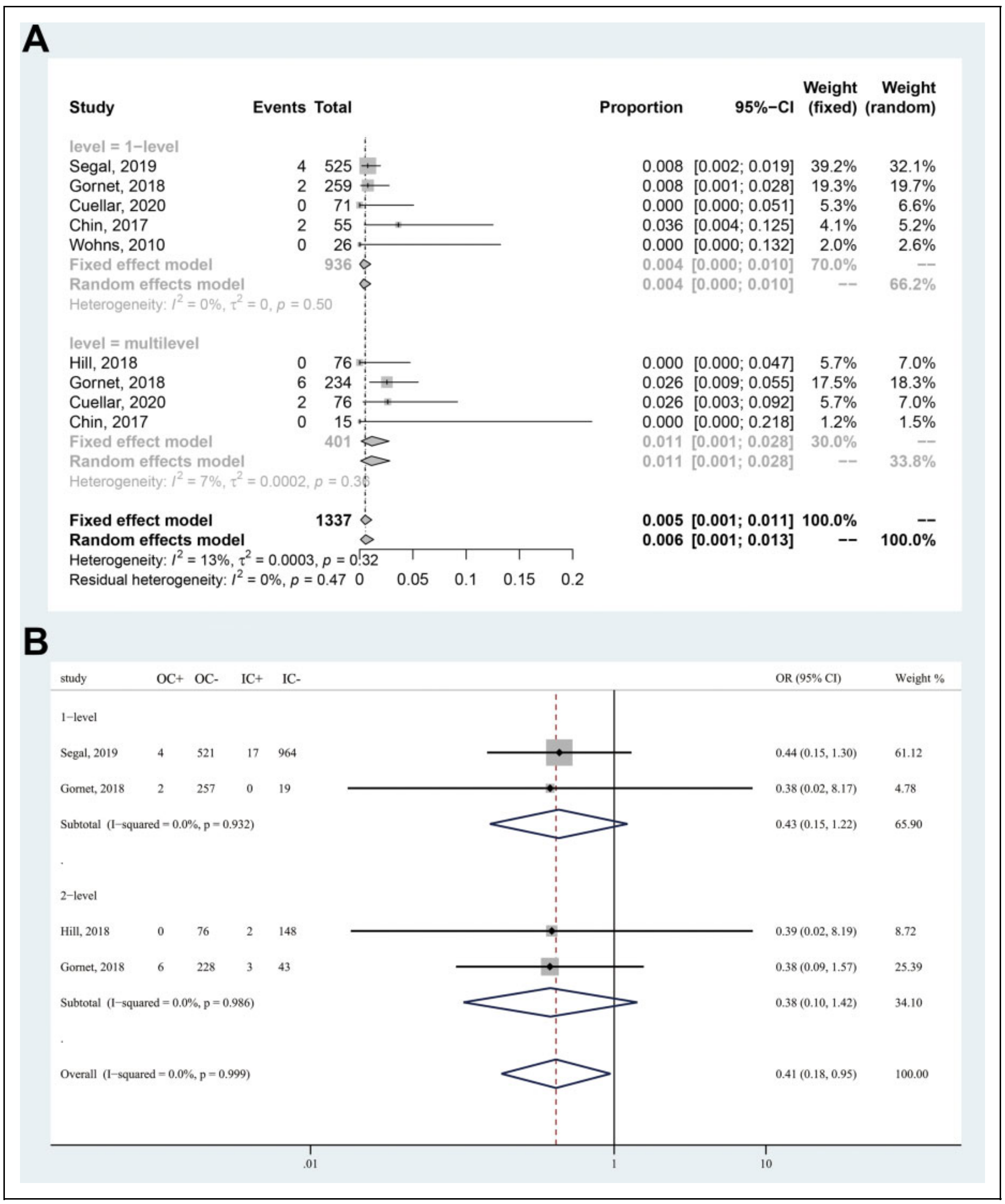

Figure 3. Forest plots of complication rate after surgery. (a) Overall complication rate after outpatient cervical disc replacement. (b) Comparison between outpatient and inpatient procedure. "C+" indicates number of patients with complications; "C−" indicates number of patients without complications; "O" indicates outpatient; "I" indicates inpatient.

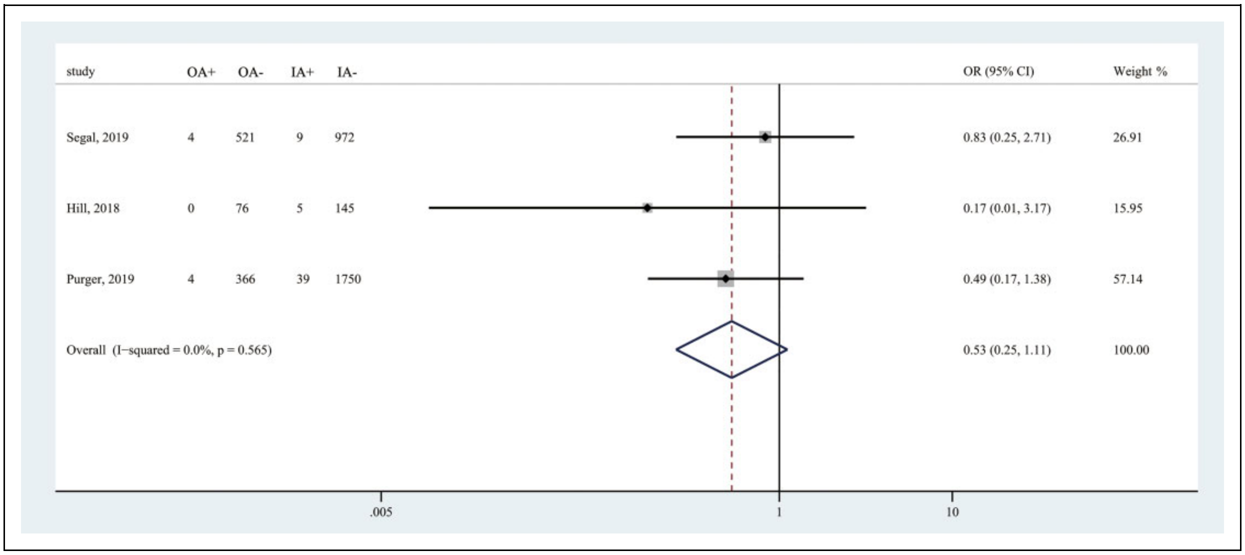

Figure 4. Forest plot of readmission rate among included studies. "A+" indicates number of patients returning to hospital; "A−" indicates number of patients not returning to hospital; "O" indicates outpatient; "I" indicates inpatient.

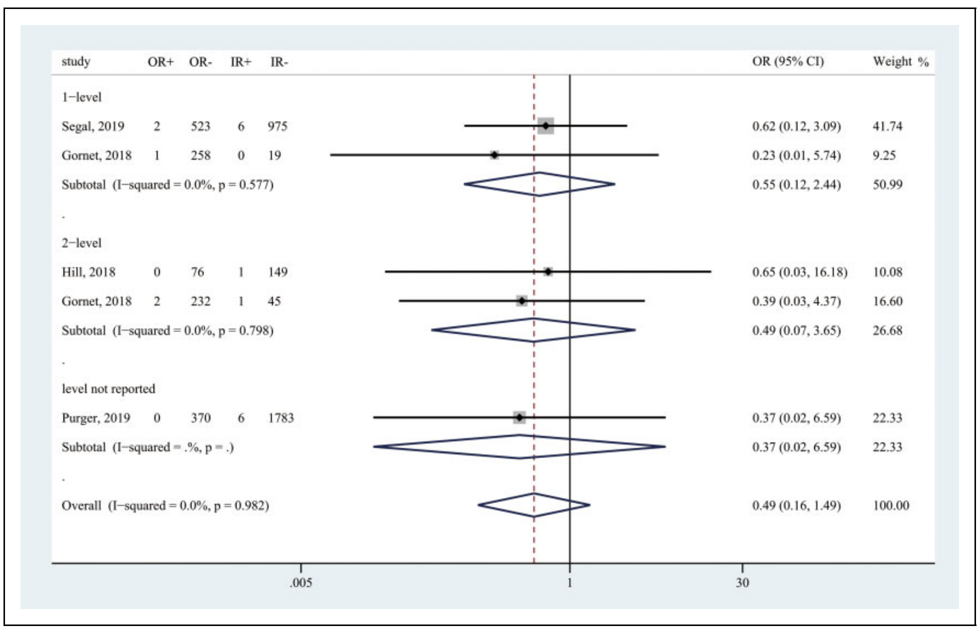

Figure 5. Forest plot of reoperation rate among included studies. "R+" indicates number of patients returning to the operation room; "R−" indicates number of patients not returning to the operation room. "O" indicates outpatient; "I" indicates inpatient.

development prospect in the outpatient surgery, because spine surgeries represent about 25% of orthopedic surgeries but contribute over 50% to the profit.[20] It is reported that the transition of inpatient spine procedures to outpatient settings could reduce 60% cost associated with the operating room and postoperative care.[20] An obvious reduction in total cost was also reported in outpatient CDR by Wohns et al[11] and Purger et al.[12] However, one of the major concerns that hindering the extension of outpatient spine surgeries is that whether they can be effectively and safely performed.

Currently, there are multiple literature reviews describing outcomes of outpatient lumbar surgery and outpatient ACDF. However, the comprehensive understanding of the safety profile of outpatient CDR is lacking. Hence, we performed this systematic review and meta-analysis of current studies. We found that the readmission and reoperation rates were similar between inpatients and outpatients. In addition, the outpatient CDR had a significantly lower incidence of overall complication and shorter operating time.

There are several reasons for the significantly lower complication rate after outpatient CDR. First, patient selection criteria for

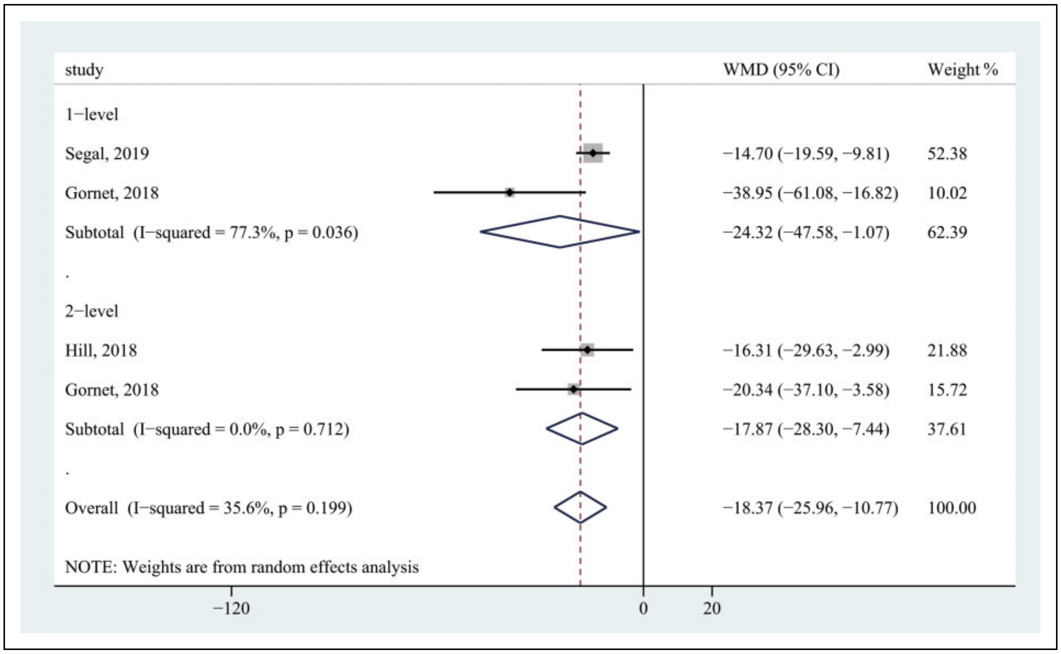

Figure 6. Forest plot of operating time among included studies.

Table 4. The Average Costs for Outpatient and Inpatient Cervical Disc Replacement.

Study	Sample size	Total cost	Actual cost	Predictors of total costs
Purger[12] (2019)	Outpatients: 370 Inpatients: 1789	Outpatient $46 404.03, Inpatient $80 055, *P* < .0001	Outpatient $11 059, Inpatient $17 033, *P* < .001	Sex, Rural-urban continuum location, Number of diagnoses, Number of chronic conditions
Wohns[11] (2010)	Outpatients: 26 Inpatient: NR	Outpatient $11 144.83, Inpatient $68 000, *P* value: NR	NR	NR

Abbreviation: NR, not reported.

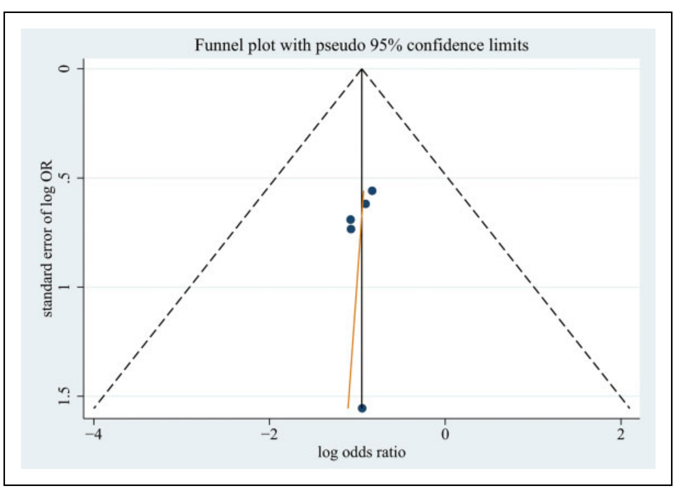

Figure 7. Funnel plot evaluating publication bias for overall complication among included studies.

outpatient CDR is strict. Usually, younger patients and healthier patients with fewer comorbidities tend to receive outpatient procedures. For instance, Purger et al[12] reported outpatients were 4 years younger than inpatients, and outpatients had significantly fewer comorbidities than inpatients. Hill et al[13] reported that overweight and diabetes were more common in patients who underwent inpatient CDR. It is believed that strict patient selection is important to optimize outcomes and safety of outpatient spine surgeries.[22-25] However, despite this consensus, currently, there is no evidence-based guideline to help with patient selection.

The second reason that may account for the advantage of outpatient CDR is that the complication criteria varied among included studies. For instance, dysphagia was not considered as a complication in included studies except for the study by Chin et al.[17] Cuellar et al[19] included nausea and vomiting as postoperative complications. Therefore, standard complication criteria, such as the Clavien-Dindo classification, could help get more accurate results. Third, the definition of outpatient surgery may also influence the result of this study. Patients could be divided into either the outpatient group or the inpatient group depending on the definition of the study. For example, some patient may stay overnight in the hospital for postoperative monitoring if their surgeries were scheduled for later in the day, and they were still divided into the outpatient group in the study by Gornet et al,[16] but could be classified into the inpatient group according to the definition of Bovonratwet et al.[15]

Although the above factors could affect the accuracy of the results, our study showed that the pooled prevalence of overall complication for outpatient CDR was very low (0.51%; 95% CI 0.10% to 1.13%). With proper patient selection, CDR can be performed safely in outpatient settings.

Except for surgical technique, anesthesiology, and patient selection, discharge criteria also could not be neglected. Mohandas et al[23] suggested that patients underwent outpatient cervical spine surgery should be evaluated with a discharge checklist or scale to determine if they can be safely discharged. However, in the included studies, only Chin et al[17] reported the discharge recommendations. In their cohort, patients received postoperative assessments by a multidisciplinary team, including surgeons, physicians, nurses, and anesthesiologists to ensure that patients are alert and neurologically intact, have no signs of swallowing and respiratory dysfunction, and are aware of the risk of serious complications after discharge. While these procedures may help guarantee patients' safety, there is no evidence-based discharge criteria at present.

Typically, most life-threatening complications such as hematomas can be detected within 4 to 6 hours after surgery.[26] However, the fear of complications without prolonged monitoring in the hospital may be another barrier of transiting CDR into outpatient settings.[26] Nowadays, with advances in information technology and the development of the internet, remote monitoring and follow-up using smartphones are applied in the management of chronic diseases and ambulatory surgeries, which can provide a practical reference for postoperative monitoring after outpatient CDR. Unfortunately, only one relevant study in outpatient spine surgery has been reported so far. Debono et al[27] found that remote monitoring using a mobile application received high rates of satisfaction and acceptance in patients who underwent ambulatory lumbar discectomy. It is possible that in the foreseeable future, the remote monitoring with smartphones will become an integral part of outpatient CDR.

Our systematic review and meta-analysis indicate that level I or II studies are absent regarding the safety and efficacy of outpatient CDR. All studies included in the quantitative analysis were retrospective studies; therefore, the accuracy of our results may be affected. In addition, the patient selection criteria, complication criteria, and the definition of outpatient surgery differed among included studies, which may also have affected the accuracy of results and limited the generalizability of our findings. However, we strictly followed the PRISMA guidelines to improve the quality of our study. Further studies with prospective design and large sample size are needed to generate evidence-based protocols for patient selection and management.

Conclusion

There is a lack of level I or II studies on the safety of outpatient CDR. However, existing studies indicate that CDR can be safely conducted in outpatient settings, with lower complication rates, shorter operating time, and similar readmission and reoperation rates compared with inpatient CDR. With careful patient selection and proper postoperative management, outpatient CDR can be used to reduce costs and improve patient satisfaction. Further prospective studies with a large sample size are needed to generate evidence-based protocols for outpatient CDR and to demonstrate the generalizability of current results.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by Science and Technology Program of Sichuan Province, China (2018SZ0045); West China Nursing Discipline Development Special Fund Project, West China Hospital, Sichuan University (HXHL19016); Post-Doctor Research Project, West China Hospital, Sichuan University (2018HXBH002).

ORCID iD

Hao Liu, MD, PhD https://orcid.org/0000-0002-6938-8774

Supplemental Material

Supplemental material for this article is available online.

References

1. Jain NS, Nguyen A, Formanek B, et al. Cervical disc replacement: trends, costs, and complications. *Asian Spine J*. Published online March 30, 2020. doi:10.31616/asj.2019.0246
2. Choi H, Purushothaman Y, Baisden J, Yoganandan N. Unique biomechanical signatures of Bryan, Prodisc C, and Prestige LP cervical disc replacements: a finite element modelling study. *Eur Spine J*. Published online October 12, 2019. doi:10.1007/s00586-019-06113-y
3. Hua W, Zhi J, Wang B, et al. Biomechanical evaluation of adjacent segment degeneration after one- or two-level anterior cervical discectomy and fusion versus cervical disc arthroplasty: a finite element analysis. *Comput Methods Programs Biomed*. 2020;189:105352. doi:10.1016/j.cmpb.2020.105352
4. Gandhi AA, Grosland NM, Kallemeyn NA, Kode S, Fredericks DC, Smucker JD. Biomechanical analysis of the cervical spine following disc degeneration, disc fusion, and disc replacement: a finite element study. *Int J Spine Surg*. 2019;13:491-500. doi:10.14444/6066
5. Lavelle WF, Riew KD, Levi AD, Florman JE. Ten-year outcomes of cervical disc replacement with the BRYAN cervical disc: results from a prospective, randomized, controlled clinical trial. *Spine (Phila Pa 1976)*. 2019;44:601-608. doi:10.1097/BRS.0000000000002907
6. Gornet MF, Burkus JK, Shaffrey ME, Schranck FW, Copay AG. Cervical disc arthroplasty: 10-year outcomes of the Prestige LP

cervical disc at a single level. *J Neurosurg Spine*. 2019;31: 317-325. doi:10.3171/2019.2.SPINE1956
7. Mehren C, Heider F, Siepe CJ, et al. Clinical and radiological outcome at 10 years of follow-up after total cervical disc replacement. *Eur Spine J*. 2017;26:2441-2449. doi:10.1007/s00586-017-5204-6
8. Kumar C, Dietz N, Sharma M, Wang D, Ugiliweneza B, Boakye M. Long-term comparison of health care utilization and reoperation rates in patients undergoing cervical disc arthroplasty and anterior cervical discectomy and fusion for cervical degenerative disc disease. *World Neurosurg*. 2020;134:e855-e865. doi:10.1016/j.wneu.2019.11.012
9. Sheperd CS, Young WF. Instrumented outpatient anterior cervical discectomy and fusion: is it safe? *Int Surg*. 2012;97:86-89. doi:10.9738/CC35.1
10. Yerneni K, Burke JF, Chunduru P, et al. Safety of outpatient anterior cervical discectomy and fusion: a systematic review and meta-analysis. *Neurosurgery*. 2020;86:30-45. doi:10.1093/neuros/nyy636
11. Wohns R. Safety and cost-effectiveness of outpatient cervical disc arthroplasty. *Surg Neurol Int*. 2010;1:77. doi:10.4103/2152-7806.73803
12. Purger DA, Pendharkar AV, Ho AL, et al. Analysis of outcomes and cost of inpatient and ambulatory anterior cervical disk replacement using a state-level database. *Clin Spine Surg*. 2019; 32:E372-E379. doi:10.1097/BSD.0000000000000840
13. Hill P, Vaishnav A, Kushwaha B, et al. Comparison of inpatient and outpatient preoperative factors and postoperative outcomes in 2-level cervical disc arthroplasty. *Neurospine*. 2018;15:376-382. doi:10.14245/ns.1836102.051
14. Segal DN, Wilson JM, Staley C, Yoon ST. Outpatient and inpatient single-level cervical total disc replacement. *Spine (Phila Pa 1976)*. 2019;44:79-83. doi:10.1097/BRS.0000000000002739
15. Bovonratwet P, Fu MC, Tyagi V, Ondeck NT, Albert TJ, Grauer JN. Safety of outpatient single-level cervical total disc replacement: a propensity-matched multi-institutional study. *Spine (Phila Pa 1976)*. 2019;44:E530-E538. doi:10.1097/BRS.0000000000002884
16. Gornet MF, Buttermann GR, Wohns R, et al. Safety and efficiency of cervical disc arthroplasty in ambulatory surgery centers vs hospital settings. *Int J Spine Surg*. 2018;12:557-564. doi:10.14444/5068
17. Chin KR, Pencle FJR, Seale JA, Pencle FK. Clinical outcomes of outpatient cervical total disc replacement compared with outpatient anterior cervical discectomy and fusion. *Spine (Phila Pa 1976)*. 2017;42:E567-E574. doi:10.1097/brs.0000000000001936
18. Chin KR, Pencle FJR, Coombs AV, Seale JA. Safety and outcome of outpatient 2-level hybrid anterior cervical discectomy and fusion plus adjacent total disc replacement. *West Indian Med J*. 2017;66:440-444. doi:10.7727/wimj.2017.033
19. Cuéllar JM, Lanman TH, Rasouli A. The safety of single and multilevel cervical total disc replacement in ambulatory surgery centers. *Spine (Phila Pa 1976)*. 2020;45:512-521. doi:10.1097/BRS.0000000000003307
20. Makanji HS, Bilolikar VK, Goyal DKC, Kurd MF. Ambulatory surgery center payment models: current trends and future directions. *J Spine Surg*. 2019;5(suppl 2):S191-S194. doi:10.21037/jss.2019.08.07
21. Pendharkar AV, Shahin MN, Ho AL, et al. Outpatient spine surgery: defining the outcomes, value, and barriers to implementation. *Neurosurg Focus*. 2018;44:E11. doi:10.3171/2018.2.FOCUS17790
22. DelSole EM, Makanji HS, Kurd MF. Current trends in ambulatory spine surgery: a systematic review. *J Spine Surg*. 2019;5(suppl 2): S124-S132. doi:10.21037/jss.2019.04.12
23. Mohandas A, Summa C, Worthington WB, et al. Best practices for outpatient anterior cervical surgery: results from a Delphi Panel. *Spine (Phila Pa 1976)*. 2017;42:E648-E659. doi:10.1097/BRS.0000000000001925
24. Helseth Ø, Lied B, Halvorsen CM, Ekseth K, Helseth E. outpatient cervical and lumbar spine surgery is feasible and safe: a consecutive single center series of 1449 patients. *Neurosurgery*. 2015;76:728-738. doi:10.1227/NEU.0000000000000746
25. Bednar DA. Description and results of a comprehensive care protocol for overnight-stay spine surgery in adults. *Spine (Phila Pa 1976)*. 2017; 42:E871-E875. doi:10.1097/BRS.0000000000001987
26. Vaishnav AS, McAnany SJ. Future endeavors in ambulatory spine surgery. *J Spine Surg*. 2019; 5(suppl 2):S139-S146. doi:10.21037/jss.2019.09.20
27. Debono B, Bousquet P, Sabatier P, Plas JY, Lescure JP, Hamel O. Postoperative monitoring with a mobile application after ambulatory lumbar discectomy: an effective tool for spine surgeons. *Eur Spine J*. 2016;25:3536-3542. doi:10.1007/s00586-016-4680-4