Meta-analysis

Comparison of 7 Surgical Interventions for Lumbar Disc Herniation: A Network Meta-analysis

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Free full manuscript: www.painphysicianjournal.com **Background:** The number of interventions on intervertebral discs rapidly increased and the treatment options for lumbar disc surgery quickly evolved. It is important that the safety and efficacy of all new innovative procedures be compared with currently accepted forms of treatment; however, the previous pairwise meta-analyses could not develop the hierarchy of these treatments.

Objectives: The purpose of the study is to perform a network meta-analysis to evaluate the clinical results of 7 surgical interventions for the treatment of lumbar disc herniation.

Study Design: Network meta-analysis of randomized controlled trials (RCTs) for multiple treatment comparisons of lumbar disc herniation.

Methods: We performed a Bayesian-framework network meta-analysis of RCTs to compare 7 surgical interventions for people with lumbar disc herniation. The eligible RCTs were identified by searching Embase, Pubmed, the Cochrane Central Register of Controlled Trials (CENTRAL), and Google scholar. Data from 3 outcomes (success, complications, and reoperation rate) were independently extracted by 2 authors.

Results: A total of 29 RCTs including 3,146 participants were finally included into this article. Our meta-analysis provides hierarchies of these 7 interventions. For the success rate the rank probability (from best to worst): percutaneous endoscopic lumber discectomy (PELD) > standard open discectomy (SOD) > standard open microsurgical discectomy (SOMD) > chemonucleolysis (CN) > microendoscopic discectomy (MED) > percutaneous laser disc decompression (PLDD) > automated percutaneous lumber discectomy (APLD). For the complication rate the rank probability (from best to worst): PELD > SOMD > SOD > MED > PLDD > CN > APLD. For the reoperation rate the rank probability (from best to worst): SOMD > SOD > MED > PLDD > PLDD > CN > APLD.

Limitations: The limitations of this network meta-analysis include the range of study populations and inconformity of the follow-up times and outcome measurements.

Conclusions: This meta-analysis provides evidence that PELD might be the best choice to increase the success rate and decrease the complication rate, moreover SOMD might be the best option to drop the reoperation rate. APLD might lead to the lowest success rate and the highest complication and reoperation rate. Higher quality RCTs and direct head to head trials are needed to confirm these results.

Key words: Lumbar disc herniation, discectomy, minimally invasive surgery, network meta-analysis

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ciatica, which is caused by nerve root compression or irritation, includes the symptoms of leg pain and occasionally neurological disturbance in the dermatome of the affected nerve root. Over 90% of

cases are due to symptomatic lumbar disc herniation (LDH) (1). Symptomatic LDH, with a reported prevalence of 1% - 3% (2), is the most common pathological process leading to spinal surgery (3,4).

The surgical approaches include open discectomy and a wide variety of minimally invasive techniques (5).

In 1934, Mixter and Barr were the first authors to treat symptomatic LDH surgically by performing an open laminectomy and discectomy (6), which has been regarded as a "standard" surgical procedure (3,5). The standard open discectomy (SOD) technique could relieve patients' pain and improve their nerve function. However, the greatest problem is the surgical trauma of paravertebral muscles, which is related to failed back surgery syndrome (1,7).

Since then the number of interventions on intervertebral discs rapidly increased and the treatment options for lumbar disc surgery quickly evolved. The surgical procedures changed over time and were continuously being refined. In the late 1960s, the surgical microscope was introduced for spinal surgery by Mahmut Gazi Yasargil (8) and his colleague Wolfhard Caspar (9), and so-called standard open microsurgical discectomy (SOMD) was introduced (10). Foley (11) introduced the microendoscopic discectomy (MED) technique in 1997. This minimally invasive technique was performed by a transmuscular approach with advanced optics (11). Besides open discectomy, other interventional techniques were developed to overcome the side effects of surgical procedures. In 1964 the American orthopedic surgeon, Lyman Smith (12) introduced chemonucleolysis (CN), a minimally invasive technique consisting only of a can-

nula and the proteolytic enzyme chymopapain, which is injected into the disc compartment to dissolve the displaced disc material. In 1975 the Japanese orthopedic surgeon Sadahisa Hijikata et al (13) first reported the development of percutaneous techniques for the treatment of certain types of lumber disc herniations. In 1985, Onik et al (14) reported the use of what has come to be called automated percutaneous lumber discectomy (APLD). Further variants of minimally invasive surgical procedures, such as percutaneous laser disc decompression (PLDD) in 1986 and percutaneous endoscopic lumber discectomy (PELD) in 1990s, were also introduced (15,16). Of the techniques available, open discectomy, performed with (micro-) or without the use of an operating microscope, is the most common, but those less invasive surgical techniques have gained popularity in recent years. Figure 1 shows the equipment used in a variety of surgical procedures.

It is particularly important that the safety and efficacy of all new innovative procedures be compared with currently accepted forms of treatment. Previous pairwise meta-analyses could not develop the hierarchy of these treatments because some treatments had not been compared one by one (17). In addition, the number of included randomized controlled trials (RCTs) was limited, which led to some potential incorrect conclusions. We aimed to compare the clinical results of 7 surgical interventions (SOD, SOMD, MED, CN, PLLD, APLD,



Fig. 1. Equipment for different surgical procedures. Fig. 1A. Instrumentation for SOMD; Fig. 1B. Instrumentation for MED; Fig. 1C. Instrumentation for CN; Fig. 1D. Instrumentation for APLD; Fig. 1E. Instrumentation for PELD; Fig. 1F. Instrumentation for PLDD.

and PELD) for the treatment of LDH and to provide a hierarchy of the comparative success rate, complication rate, and reoperation rate.

Methods

Criteria for Considering Studies

We only included RCTs, which compared ratings of success and incidences of complications and reoperations of the 7 interventions (SOD, SOMD, MED, CN, PLLD, APLD, and PELD) in people with LDH.

Studies were included if they met the following criteria: (1) Study design: RCTs; (2) Participants: patients with LDH who have indications for surgical intervention; (3) Interventions and comparisons: therapy that included 2 of the 7 interventions; (4) Outcomes: the studies reported rates of success and incidences of complications and reoperations (to pool the results, ratings of excellent, good, and fair were classified as "success" and poor, unimproved, and worse as "failure").

Trials were excluded if: (1) they were abstracts, letters, or meeting proceedings; (2) they contained repeated data or did not report the outcomes of interest; and (3) the duration of follow-up was < 6 months.

Search Methods and Study Selection

We searched EMBASE (from 1974 to May 2016), PubMed (from 1966 to May 2016), the Cochrane Central Register of Controlled Trials (CENTRAL) (The Cochrane Library, most recent issue), and Google scholar. Key words and MeSH terms including "lumbar disc herniation," "open discectomy," "microsurgery," "minimally invasive surgery," and "percutaneous discectomy" were used in the search strategy. We also viewed the reference lists of the included studies for any additional papers. We included only articles written in English.

Two authors independently made the selection based on the title and abstract. Any disagreement between the 2 authors was resolved by discussion. If there was no consensus, a third reviewer (Yuanlong Xie) was consulted.

Data Collection and quality Assessment

We used the Cochrane risk of bias tool to assess risk bias of included studies (18). The tool has 7 domains including random sequence generation, allocation concealment, blinding of participants and experimenters, blinding of outcome assessment, incomplete outcome data, selective reporting, and other bias. Since it was sometimes difficult to blind surgeons and patients, we did not include the blinding items of risk of bias in our analysis. The classification of the judgment for each domain was low risk of bias, high risk of bias, or unclear risk of bias, and 2 authors independently evaluated the risk of the studies.

Data Synthesis and Analysis

We used pairwise meta-analyses for studies which directly compared different treatments by using Stata software (version 12.0, StataCorp, College Station, TX). DerSimonian and Laird random effects model was used. The pooled estimates of odds ratios (ORs) and 95% confidence intervals (CI) of 3 outcomes were shown. Chi-square test and I2 test were used for testing heterogeneity among the studies. Then network meta-analysis was performed by using WinBUGS (version 1.4.3, MRC Biostatistics Unit, Cambridge, UK) with random effects models developed by Chaimani (downloaded from www.mtm.uoi.gr) (19). We used the Markov Chains Monte Carlo (MCMC) method to get results, which were reported as posterior distribution median with 95% CI. Non-informative uniform and normal prior distributions were performed to fit the model (20). An automatically generated starting value was used to fit the model. For each analysis, we used 100,000 iterations after an initial burn-in of 5,000 (21). To rank the treatments, we used 2 ways. Firstly, we used posterior probabilities of outcomes to calculate probabilities of treatment ranking. Secondly, we used the surface under the cumulative ranking probabilities (SUCRA) to indicate which treatment was the best one (22).

The funnel plot was used to identify possible publication bias if the number of included studies in one comparison was larger than 10. The sensitivity analysis was performed by excluding studies with different durations of follow-up and studies with high risk of bias. The Cochrane review protocol was not required for this research.

RESULTS

The PRISMA flow diagram of study selection is depicted in Fig. 2. The search was performed on April 10, 2016, and 1,025 references were identified in the primary search and 3 through other sources. After removal of duplicates, irrelevant studies, case reports, and studies that were not comparative studies, 72 records were screened. Twenty-nine studies with 31 published articles were eligible for inclusion, and others were not selected for various reasons. Data from these studies





Fig. 3. Network of treated comparisons. The network plot shows direct and indirect comparisons. The size of the nodes represents the total sample size of treatments. The lines' thickness corresponds to the number of trials that compare each other.

were included in the meta-analysis (23-53). Figure 3 shows the network of treated comparisons.

Table 1 provides a summary of the studies included in the review. A total of 3,146 participants were included in this meta-analysis. The study sample size ranged from 20 to 358. These studies were published between 1983 and 2016.

Risk of Bias in Included Studies

Figure 4 shows the risk of bias in all 29 studies. Two studies had a high risk of bias for sequence allocation and concealment because they were reported as openlabel clinical trials (30,39). Since it was sometimes difficult to blind surgeons and patients, we did not include the blinding items for risk of bias in our analysis.

Success Rate-related Outcomes

A total of 762 patients were assigned to SOD therapy, 237 to SOMD therapy, 468 to CN therapy, 250 to MED therapy, 219 to PELD therapy, 41 to APLD therapy, and 132 to PLLD therapy.

Compared with SOD therapy, PELD (OR 1.47, 95% CI 0.45 – 3.70) yielded the most significant effect on success rate, followed by CN (OR 0.78, 0.44 – 1.26), SOMD (OR 0.77, 0.19 – 2.18), PLDD (OR 0.49, 0.15 – 1.25), and APLD (OR 0.14, 0.02 – 0.55). Details pertaining to other comparisons are listed Table 2.

Complication Rate-related Outcomes

A total of 460 patients were assigned to SOD therapy, 461 to SOMD therapy, 188 to CN therapy, 456 to MED therapy, 221 to PELD therapy, 69 to APLD therapy, and 63 to PLLD therapy.

Compared with SOD therapy, APLD (OR 172, 95% CI 0.27 – 401) had the most significant effect on complication rate, followed by CN (OR 76.16, 0.31 - 174), PLDD (OR 2.52, 0.20 - 10.41), MED (OR 2.29, 0.98 - 4.78), SOMD (OR 1.78, 0.65 - 4.24), and PELD (OR 0.37, 0.09 - 0.98). Details pertaining to other comparisons are listed Table 3.

Reoperation Rate-related Outcomes

A total of 559 patients were assigned to SOD therapy, 551 to SOMD therapy, 313 to CN therapy, 456 to MED therapy, 223 to PELD therapy, 110 to APLD therapy, and 153 to PLLD therapy.

Compared with SOD therapy, APLD (OR 46.75, 95% CI 2.78 – 233) had the most significant effect on complication rate, followed by CN (OR 15.89, 4.07 – 47.53),

StudiesRule foundsEndine-up (\$750)Rollow-up (\$750)Ansat 									Outcome	
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Lavignolic et al (38) (1987)France $CNVS SOD$ 2.7 3.58 0 $150/142$ 3.235 NA LeeSH et al (39)(2006)South KoreaPELD VS SOMD 2.7 60 0 $29/28$ $1/2$ NA LeeSH et al (49)(1993)GermanyPELD VS SOMD 2.7 60 0 $29/28$ $1/2$ NA Mayer et al (41)(1992)UKChinaPELD VS SOMD 2.7 60 0 $29/28$ $1/7$ $3/3$ NA Muralikutan et al (41)(1992)UKChinaPELD VS SOMD 0.5 200 0.6 0 0 $9/9$ $1/1$ $1/0$ Pan, Let al (42)(2016)ChinaPELD VS SOMD 0.5 0.5 200 0.6 0.7 $28/39$ $3/12$ Pan, Zet al (43)(2005)FranceChinaPELD VS SOMD 1 106 0.6 0 0.6 0.7 $28/39$ $3/12$ Pan, Zet al (43)(2005)FranceChinaPELD VS SOMD 2 40 0 0.6 0.7 $28/39$ $3/12$ Revel et al (44)(2008)GermanyPELD VS SOMD 2 0.5 200 $29/2$ $29/39$ $3/12$ Revel et al (45)(2008)GermanyPELD VS SOMD 1.3 0.6 0.7 0.7 $28/39$ $3/12$ Revel et al (49)(1900)SermanyPELD VS SOMD 1.3 0.6 0.7 0.7 0.7 0.7 0.7 0.7 Revel et al (49)(1900)SermanyPELD VS SOMD 1.3	Krugluger et al (37) (2000)	Austria	CN VS APLD	2	22	0	NA	NA	NA	1/2
LesSH et al (39)(2006)South KoreaPELD VS SOMD 2.7 60 0 $29/28$ $1/2$ NAMayer et al (40) (1993)GermanyPELD VS SOMD 2 40 0 $17/17$ $3/3$ NAMayer et al (41) (1992)UKNUKNVS SODD 1 92 MA $18/23$ $28/23$ $1/10$ Pan, Let al (41) (1992)UKNUKNUVS SODD 1 92 0 9 $1/17$ $3/3$ $1/10$ Pan, Let al (41) (1992)ChinaPLD VS SODD 0.5 20 0 9 $1/11$ $1/10$ Pan, Let al (42) (2014)ChinaPELD VS SODD 0.5 20 0 0 $46/52$ $2/33$ $2/32$ Pan, Let al (45) (2007)BrazilMED VS SOMD 2 40 0 0 0 0 $3/12$ Revel et al (40) (2008)FranceNED VS SOMD 2 40 0 0 0 0 $3/12$ Ruet et al (40) (2008)GermanyPELD VS SOMD 2 20 0 0 0 0 0 0 Ruet et al (40) (1909)GermanyPELD VS SOMD 1.3 0 0 0 0 0 0 0 0 0 Ruet et al (40) (1990)GermanyPELD VS SOMD 1.3 0 0 0 0 0 0 0 0 0 Ruet et al (40) (1990)SwitzerlandPELD VS SOMD 1.3 0 0 0 0 0	Lavignolle et al (38) (1987)	France	CN VS SOD	2	358	0	150/142	32/35	NA	NA
Mayer et al (40) (1993)GermanyPELD VS SOMD2400 $17/17$ 3/3NAMaralikutran et al (41) (192)UKCNVS SOD192NA18/2328/231/0Pan, L et al (42) (2014)ChinaPLDD VS SOD0.5209/91/11/01/0Pan, L et al (42) (2014)ChinaPELD VS SOD11069/91/11/0Pan, L et al (42) (2014)ChinaPELD VS SOD110609/91/11/0Pan, L et al (42) (2010)FranceCNVS APLD116608/552/33/12Revel et al (44) (2008)FranceCNVS SOMD2400NANA3/1Reper et al (45) (2007)BrazilMED VS SOMD2400NANA3/1Revel et al (45) (2008)GermanyPELD VS SOMD2400NANA3/1Revel et al (45) (2008)GermanyPELD VS SOMD1.3600NANA3/1Ruet et al (45) (2008)GermanyPELD VS SOMD1.36002/403/43/1Ruet et al (45) (2008)SwitzerlandMED VS SOMD1.36002/403/43/1Ruet et al (45) (2008)SwitzerlandMED VS SOMD1.36002/403/43/1Ruet et al (45) (2008)SwitzerlandMED VS SOMD1.36002/403/43/1 <td< td=""><td>Lee,SH et al (39)(2006)</td><td>South Korea</td><td>PELD VS SOMD</td><td>2.7</td><td>60</td><td>0</td><td>29/28</td><td>1/2</td><td>NA</td><td>1/0</td></td<>	Lee,SH et al (39)(2006)	South Korea	PELD VS SOMD	2.7	60	0	29/28	1/2	NA	1/0
Muralikutan et al (41) (1902)UKCN VS SOD192NA18/2328/231/0Pan, Let al (22) (2014)ChinaPLD VS SOD 0.5 20 $9/9$ $1/1$ $1/0$ Pan, Let al (42) (2014)ChinaPLD VS SOD 0.5 20 $9/9$ $1/1$ $1/0$ Pan, Z et al (43) (2016)ChinaPELD VS SOD 1 106 0 $46/53$ $2/3$ $3/12$ Pan, Z et al (43) (2007)BrazilCNVS APLD 1 165 24 $4/4/30$ $28/39$ $5/7$ Revelet al (44) (2008)GermanyPELD VS SOMD 2 40 0 NA NA $3/12$ Righesso et al (45) (2007)BrazilMED VS SOMD 2 40 0 NA NA $3/12$ Righesso et al (45) (2008)GermanyPELD VS SOMD 2 40 0 NA NA $3/12$ Righesso et al (45) (2008)GermanyPELD VS SOMD 2 40 0 NA NA $3/12$ Righesso et al (45) (2008)GermanyPELD VS SOMD 1 1 165 $2/12$ $3/12$ Righesto et al (40) (2008)GermanyPELD VS SOMD 1 1 100 2 $2/10$ $3/12$ Righesto et al (49) (2010)Ital (49) (2010)Ital (49) (2010)Nath 100 2 $2/10$ $2/10$ $3/14$ $10/16^2$ Suble et al (50) (1993)SwedenMED VS SODItal (40) 2 $2/10$ $2/10$ $10/16^2$ <td>Mayer et al (40) (1993)</td> <td>Germany</td> <td>PELD VS SOMD</td> <td>2</td> <td>40</td> <td>0</td> <td>17/17</td> <td>3/3</td> <td>NA</td> <td>3/0</td>	Mayer et al (40) (1993)	Germany	PELD VS SOMD	2	40	0	17/17	3/3	NA	3/0
Pan, Let al (42) (2014)ChinaPLDD VS SOD 0.5 20 $9/9$ $1/1$ $1/0$ Pan, Let al (42) (2016)ChinaPELD VS SOD1 106 0 $46/55$ $2/3$ $3/12$ Pan, Z et al (43) (2016)ChinaPELD VS SOD1 106 0 $46/55$ $2/3$ $3/12$ Revel et al (44) (1993)FranceCNVVS APLD 1 165 24 $44/30$ $28/39$ $5/7$ Righesso et al (45) (2007)BrazilMED VS SOMD 2 40 0 NA NA NA $3/12$ Ruetten et al (46) (2008)GermanyPELD VS SOMD 1.3 60 0 NA NA $3/12$ Ryang et al (47) (2008)GermanyMED VS SOMD 1.3 60 0 NA NA $3/12$ Ryang et al (48) (1990)SwitzerlandNED VS SOMD 1.3 60 0 NA NA NA Vall et al (49) (2010)ItalyMED VS SOMD 2 240 2 $3/4$ NA Vall berg et al (50) (1933)SwedenMED VS SOD 1 1 160 2 $4/3$ $3/12$ Vall berg et al (51) (1980)NetherlandsNetherlands 1 1 1 1 1 1 1 1 1 1 1 1 Vall berg et al (51) (1980)NetherlandsNetherlands 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Muralikuttan et al (41) (1992)	UK	CN VS SOD	1	92	NA	18/23	28/23	1/0	9/1
Pan, Z et al (43) (2016)ChinaPELD VS SOD1106046/552/33/12Revel et al (44) (193)France $CNVS APLD$ 11652444/3028/395/7Revel et al (44) (2008)BrazilMED VS SOMD2400NANA3/1Ruetten et al (45) (2008)GermanyPELD VS SOMD2400NA3/1Ruetten et al (45) (2008)GermanyPELD VS SOMD220022/403/43/1Ryang et al (47) (2008)GermanyMED VS SOMD1.3600NANA2/6Ryang et al (47) (2008)GermanyMED VS SOMD1.3600NANA2/6Ryang et al (47) (2008)GermanyMED VS SOMD1.3600NANA2/6Ryang et al (47) (2008)SwitzerlandNED VS SOMD1.36002/403/4NAStula et al (49) (2010)SwitzerlandNED VS SODD22402/403/4NATel et al (49) (2010)SwetenMED VS SOD22402/403/4NATulberg et al (50) (1933)SwetenMED VS SOD16022/403/4NAVan Alphen et al (51) (1989)NetherlandsON VS SOD1112/101/10Van Alphen et al (51) (1989)NetherlandsON VS SOD1111/101/10Van Alphen et al (51) (1989)NH <td>Pan, L et al (42) (2014)</td> <td>China</td> <td>PLDD VS SOD</td> <td>0.5</td> <td>20</td> <td>0</td> <td>9/6</td> <td>1/1</td> <td>1/0</td> <td>NA</td>	Pan, L et al (42) (2014)	China	PLDD VS SOD	0.5	20	0	9/6	1/1	1/0	NA
Revel et al $(44)(1993)$ FranceCNVS APLDI1652444/3028/395/7Righesso et al $(45)(2007)$ BrazilMEDVS SOMD2400NANA3/1Ruetten et al $(45)(2008)$ GermanyPELDVS SOMD220022589/822/53/12Ryang et al $(47)(2008)$ GermanyMED VS SOMD1.3600NANA2/6Ryang et al $(47)(2008)$ GermanyMED VS SOMD1.3600NANA2/6Ryang et al $(47)(2008)$ SwitzerlandOCNVS SODNA6902/403/4NAFul et al $(49)(2010)$ ItalyMED VS SOD224028NANA19/10/5Teil et al $(49)(2010)$ ItalyMED VS SOD224028NANA19/10/5Van Alpher et al $(51)(1989)$ NetherlandsOCNVS SOD115104/562/112NAVan Alpher et al $(51)(1989)$ NetherlandsOCNVS SOD115104/562/12NAVan Alpher et al $(51)(1989)$ NetherlandsOCNVS SOD115115110/1511/1511/15Van Alpher et al $(51)(1989)$ NetherlandsOCNVS SOD1115110/1511/15Van Alpher et al $(51)(1989)$ NetherlandsOCNVS SOD1115110/1511/15Van Alpher et al $(51)(1989)$ NUNUOCNVS SOD11 <td< td=""><td>Pan, Z et al (43) (2016)</td><td>China</td><td>PELD VS SOD</td><td>1</td><td>106</td><td>0</td><td>46/55</td><td>2/3</td><td>3/12</td><td>NA</td></td<>	Pan, Z et al (43) (2016)	China	PELD VS SOD	1	106	0	46/55	2/3	3/12	NA
Righesso et al (45) (2007)BrazilMED VS SOMD2400NANA3/1Ruetten et al (46) (2008)GermanyPELD VS SOMD22002289/822/53/12Ryang et al (47) (2008)GermanyMED VS SOMD1.3600NANA $2/6$ Studa et al (47) (2008)GermanyMED VS SOMD1.3600NA $2/6$ $3/12$ Studa et al (47) (2008)SwitzerlandOCN VS SODNA69022/40 $3/4$ NATel et al (49) (2010)ItalyMED VS SOD224028NA $9/10/5$ Tullberg et al (50) (1933)SwedenMED VS SOD16022/40 $3/4$ $N/10/5$ Van Alphen et al (51) (1989)NetherlandsCN VS SOD11510 $4/6/56$ $2/1/2$ $3/12$	Revel et al (44)(1993)	France	CN VS APLD	1	165	24	44/30	28/39	5/7	3/1
Ruetten et al (46) (2008) Germany PELD VS SOMD 2 200 22 89/82 2/5 3/12 Ryang et al (47) (2008) Germany MED VS SOMD 1.3 60 0 NA NA 2/6 3/14 Ryang et al (47) (2008) Germany MED VS SOMD 1.3 60 0 NA NA 2/6 Stula et al (49) (2010) Switzerland CNVS SOD NA 69 0 2/40 3/4 NA Teile et al (49) (2010) Italy MED VS SODD 2 240 28 NA NA 9/10/5 Teile et al (51) (1993) Sweden MED VS SODD 1 60 2 2/40 3/4 NA Van Alphen et al (51) (1989) Netherlands CNV SODD 1 60 2 2/5/26 4/3 3/1	Righesso et al (45) (2007)	Brazil	MED VS SOMD	2	40	0	NA	NA	3/1	1/1
Ryang et al (47) (2008) Germany MED VS SOMD 1.3 60 0 NA NA 2/6 Stula et al (49) (2010) Switzerland CNVS SOD NA 69 0 2/40 3/4 NA Teil et al (49) (2010) Italy MED VS SOMD VS SOD 2 240 28 NA NA 19/10/5 Teil et al (49) (2010) Italy MED VS SOMD VS SOD 2 240 28 NA NA 19/10/5 Tullberg et al (50) (1993) Sweden MED VS SOD 1 60 2 2/40 3/4 NA Van Alphen et al (51) (1989) Netherlands CNVS SOD 1 60 2 2/5/26 4/3 3/1 Van Alphen et al (51) (1989) Netherlands CNVS SOD 1 151 0 4/6/56 2/1/2 NA	Ruetten et al (46) (2008)	Germany	PELD VS SOMD	2	200	22	89/82	2/5	3/12	7/10
Stula et al (48) (190) Switzerland CNVS SOD NA 69 0 22/40 3/4 NA Teil et al (49) (2010) Italy MED VS SOMD VS SOD 2 240 28 NA 19/10/5 Tullberg et al (50) (1933) Sweden MED VS SOD 1 60 2 25/26 4/3 3/1 van Alphen et al (51) (1989) Netherlands CNVS SOD 1 151 0 46/56 27/12 NA	Ryang et al (47) (2008)	Germany	MED VS SOMD	1.3	60	0	NA	NA	2/6	2/4
Teil et al (49) (2010) Italy MED VS SOMD VS SOD 2 240 28 NA NA 19/10/5 Tullberg et al (50) (1993) Sweden MED VS SOD 1 60 2 25/26 4/3 3/1 van Alphen et al (51) (1989) Netherlands CN VS SOD 1 151 0 46/56 27/12 NA	Stula et al (48) (1990)	Switzerland	CN VS SOD	NA	69	0	22/40	3/4	NA	2/1
Tullberg et al (50) (1993) Sweden MED VS SOD 1 60 2 25/26 4/3 3/1 van Alphen et al (51) (1989) Netherlands CN VS SOD 1 151 0 46/56 27/12 NA	Teil et al (49) (2010)	Italy	MED VS SOMD VS SOD	2	240	28	NA	NA	19/10/5	8/3/2
van Alphen et al (51) (1989) Netherlands CN VS SOD 1 151 0 46/56 27/12 NA vvv-ul-col (col (col (col (col (col (col (col (Tullberg et al (50) (1993)	Sweden	MED VS SOD	1	60	2	25/26	4/3	3/1	1/1
1/1 1/1 1/1 1/1 1/1 1/1 1/1 1/1 1/1 1/1	van Alphen et al (51) (1989)	Netherlands	CN VS SOD	1	151	0	46/56	27/12	NA	18/2
NUTCHAR ET al (22) (2015) UN	Wardlaw et al (52) (2013)	UK	CN VS SOD	10-13	100	39	28/25	4/4	1/1	9/1

Comparison of Surgical Interventions for Lumbar Disc Herniation



Fig. 4. Risk of bias graph. Five items introduced by Cochrane Handbook were considered. Blinding was canceled due to impractical implementation.

Table 2 Possilia	f	notroarle	moto	anal	waia	for		rate related	outoomoo
1 able 2. Results (<i>י</i> ן	пениогк	meia	-anai	ysis.	jor	success	rate-retatea	outcomes.

	SOD	SOMD	CN	MED	PELD	APLD
SOD	1					
SOMD	0.77 [0.19-2.18]	1				
CN	0.78 [0.44-1.26]	1.44 [0.34-3.93]	1			
MED	0.74 [0.31-1.62]	1.42 [0.26-4.65]	1.03 [0.35-2.54]	1		
PELD	1.47 [0.45-3.70]	2.30 [0.69-5.79]	1.99 [0.57-5.25]	2.33 [0.49-6.85]	1	
APLD	0.14 [0.02-0.55]	0.18 [0.04-0.52]	0.19 [0.02-0.75]	0.22 [0.02-0.91]	0.10 [0.01-0.38]	1
PLDD	0.49 [0.15-1.25]	0.79 [0.24-1.97]	0.65 [0.22-1.58]	0.78 [0.15-2.26]	0.41 [0.10-1.15]	6.77 [0.85-23.45]

Table 3. Results of network meta-analysis for complication rate-related outcomes.

	SOD	SOMD	CN	MED	PELD	APLD
SOD	1					
SOMD	1.78 [0.65-4.42]	1				
CN	76.16 [0.31-174]	48.21 [0.17-119]	1			
MED	2.29 [0.98-4.78]	1.43 [0.60-2.78]	1.23 [0.01-7.88]	1		
PELD	0.37 [0.09-0.98]	0.23 [0.06-0.58]	0.22 [0.01-1.32]	0.18 [0.04-0.48]	1	
APLD	172 [0.27-401]	119.1 [0.16-282]	2.67 [0.29-9.08]	92.24 [0.12-201]	996.2 [0.75-1586]	1
PLDD	2.52 [0.20-10.41]	1.4 [0.14-5.21]	1.32 [0.01-8.18]	1.17 [0.09-4.56]	10.23 [0.54-39.94]	2.49 [0.01-8.31]

PELD (OR 4.36, 0.17 – 18.16), PLDD (OR 3.34, 0.22 – 14.78), MED (OR 1.66, 0.29 – 5.95), and SOMD (OR 1.15, 0.17 – 4.29). Details pertaining to other comparisons are listed Table 4.

Ranking of Treatments

In Fig. 5, we summarized the ranking of the 7 surgical interventions in terms of the success rate, complication rate, and reoperation rate. For a higher

success rate, PELD might be the best intervention and APLD most likely the worst. For lowering the complication rate, PELD might be the best option and APLD the worst. For lowering the reoperation rate, SOMD might be the best therapy and APLD the worst.

Publication Bias and Sensitivity Analyses

Publication bias was not assessed because the number of studies was limited (< 10). Sensitivity analy-

	SOD	SOMD	CN	MED	PELD	APLD
SOD	1					
SOMD	1.15 [0.17-4.29]	1				
CN	15.89 [4.07-47.53]	26.78 [2.45-105]	1			
MED	1.66 [0.29-5.94]	1.97 [0.38-6.08]	0.15 [0.01-0.61]	1		
PELD	4.36 [0.17-18.16]	2.91 [0.37-11.97]	0.34 [0.01-1.55]	2.87 [0.16-12.54]	1	
APLD	46.75 [2.78-233]	60.8 [3.05-298]	3.22 [0.23-15.04]	43.98 [1.77-224]	46.07 [0.82-246]	1
PLDD	3.34 [0.22-14.78]	3.98 [0.26-16.87]	0.30 [0.01-1.39]	2.95 [0.14-13.69]	3.08 [0.06-14.87]	0.25 [0.01-1.22]

Table 4. Results of network meta-analysis for reoperation rate-related outcomes.

ses where 2 studies with a high risk of bias were excluded did not change the result.

DISCUSSION

Summary of Main Results

The network meta-analysis provides hierarchies for the success, complication, and reoperation rates of the 7 different in interventions in people with LDH. The meta-analysis indicated that: For increasing the success rate, PELD might be the best surgical intervention and APLD might be the worst. For decreasing the complication rate, PELD might be the best option and APLD might be the worst. For decreasing the reoperation rate, SOMD might be the best therapy and APLD might be the worst.

Strengths and Limitations

There were some strengths in this article: (1) we used a comprehensive search strategy to minimize the possibility of publication bias; (2) the posterior probabilities of outcomes and SUCRA were used to distinguish the subtle differences among 7 surgical interventions; (3) the article referred to the results of direct and indirect comparisons; and (4) only RCTs that described random sequence generation were included in this article.

However, the results of the review should be interpreted under some limitations. First, both the number of the included studies and the sample size were small, which might affect the outcome. Moreove,r for the success rate, the sample size for APLD was less than 100. For the complication rate, the sample size for APLD and PLDD were also less than 100. Third, there was substantial heterogeneity due to the inconformity regarding the duration of follow-up. Fourth, for the studies where the success, complication, and reoperation rates were second-



ary outcomes, the number time points was insufficient which might underestimate the outcomes. Fifth, our article used summary data instead of individual patient data, which might lead to the loss of some covariates at the individual patient level. Finally, due to the difference in indications in the included studies, the results might be influenced and need to be carefully applied.

Agreements and Disagreements in the Current Literature

In prior meta-analyses Rasouli and colleagues (54) showed there were no significant difference between minimally invasive discectomy (PELD/APLD) and SOD/SOMD for surgical procedure-related complication rates (OR 1.01, 95% CI 0.61 to 1.66, P = 0.97 I² = 33%) and reoperation rate (OR 2.13, 95% CI 1.01 to 4.49, P = 0.65, I² = 0%); He et al (55) compared the complication rates between MED and SOD (OR 1.27, 95% CI 0.63 to 2.59, P = 0.22, I² = 33%), and no significant differences were found. Gibson and Waddell (3) found SOD significantly decreased the reoperation rate compared to CN (OR

0.07, 95% CI 0.12 to 0.08, P < 0.001, $I^2 = 0\%$); however, the difference of failure rates between the 2 procedure were insignificant (OR 0.37, 95% CI 0.13 to 1.05, P = 0.006, $I^2 = 78.6\%$).

Although previous studies have different combinations, the ranking methods are relatively rough, and their included interventions were not comprehensive. Therefore, we performed this network meta-analysis. Overall, our results agree with the previous research and we were able to rank these interventions which the previous reviews did not.

Conclusions

This meta-analysis provides evidence that PELD might be the best choice to increase the success rate and decrease the complication rate; moreover, SOMD might be the best option to lower the reoperation rate. APLD might lead to the lowest success rate and the highest complication and reoperation rates. Higher quality RCTs and direct head to head trials are needed to confirm these results.

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