REVIEW



Posterior fossa decompression with and without duraplasty for the treatment of Chiari malformation type I—a systematic review and meta-analysis

Hao Xu^{1,3} · LinYang Chu² · Rui He² · Chang Ge² · Ting Lei¹

Received: 16 September 2015 / Revised: 7 March 2016 / Accepted: 7 March 2016 / Published online: 1 June 2016 © Springer-Verlag Berlin Heidelberg 2016

Abstract The treatment of Chiari malformation type 1 (CM-I) with posterior fossa decompression without (PFD) or with duraplasty (PFDD) is controversial. Our aim is to compare the clinical outcome between the two methods for the treatment of CM-I. In this paper, the authors report a systematic review and meta-analysis of operation time, clinical improvement, and complications of PFD compared with PFDD for the treatment of CM-I. Randomized or non-randomized controlled trials of PFD and PFDD were considered for inclusion. Twelve published reports of eligible studies involving 841participants meet the inclusion criteria. There is significant difference in the operative time [mean difference = -74.63, 95 % CI (-83.02, -66.25), p < 0.05] in favor of PFD compared with PFDD. There is significant difference in overall complication rates [mean difference = 0.34, 95 % CI (0.19, 0.60), p < 0.05] and rates of CSF leak [mean difference = 0.24, 95 % CI (0.07,

Hao Xu, LinYang Chu, Rui He and Chang Ge contributed equally to this work.

Ting Lei tlei@tjh.tjmu.edu.cn

- ¹ Department of Neurosurgery, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China
- ² Department of Orthopedic, Anhui Provincial Hospital Affiliated to Anhui Medical University, Hefei, Anhui 230001, People's Republic of China
- ³ Department of Neurosurgery, Anhui Provincial Hospital Affiliated to Anhui Medical University, Hefei, Anhui 230001, People's Republic of China

0.78), p < 0.05] in favor of PFD groups. However, there is significant difference in the clinical improvement rate in favor of the PFDD group [mean difference = 0.85, 95 % CI (0.73, 0.99), p < 0.05]. Although PFDD is related with longer operation time and higher CSF leak rate, it can still be considered as a preferable treatment option for most CM-I patients for its higher improvement rate. More evidence from advanced multi-center studies are needed to provide illumination for the surgical decision making of CM-I.

Keywords Posterior fossa decompression · Duraplasty · Chiari malformation type I · Systematic review · Meta-analysis

Introduction

The Chiari I malformation (CM-I) is the most common condition in the field of craniocervical junction [2, 4]. Surgery is the only treatment available for CM-I; however, multiple methods coexist for this procedure. Posterior fossa decompression with (PFDD) or without duraplasty (PFD) is the surgical treatment of choice [5, 18, 23]. With the trend towards minimally invasive techniques, the duraplasty portion of the procedure has become debatable for the elimination of it can lead to decreased complications. However, PFD is likely to cause higher rates of reoperation as it displays a tendency of inadequate depression [3]. Currently, the consensus on ideal surgical intervention for this condition has not been reached.

This paper will focus on the current literature examining outcomes following PFD compared to PFDD. We report a comprehensive systematic review and meta-analysis to evaluate the clinical advantages of the two methods for the treatment of CM-I.

Methodology

Search criteria

All full text randomized and non-randomized controlled trials, comparing the clinical outcomes of PFD and PFDD for the patients with CM-I in published studies, were included. Case reports of less than ten subjects, comments, letters, editorials, protocols, guidelines, animal studies, and cadaver articles were excluded.

Search strategy

The Medline, Embase, Cochrane library, Ovid, and CBM databases were searched for English-language articles published from May 1995 to May 2015. Unpublished studies were excluded. Prespecified search terms were "posterior fossa decompression", "duraplasty," and "chiari malformation type I." Titles, abstracts, and subject headings were searched. The reference lists of all included articles and review papers were scrutinized for additional publications.

Search selection

Two reviewers independently assessed the titles and abstracts of each identified citation. The full text of potential articles were ordered and evaluated against the eligibility criteria. Any disagreements were resolved by discussion.

Data extraction

Each reviewer extracted data independently from each included paper. All data was tabulated onto a predefined spreadsheet. All articles were anonymized for author name, institution, journal title, and year of publication to blind reviewers during data extraction, appraisal, and analysis.

Outcome measures

The outcome measures were operation time, complications (neurological complications, cerebrospinal fluid (CSF) leak, wound infection, pseudomeningocele, and aseptic meningitis), clinical improvement, and recurrence rate.

Analysis

The mean differences and 95 % confidence intervals of each outcome were assessed by comparing PFDD and PFD groups, and the statistical heterogeneity was measured by using I^2 statistics. The I^2 test for heterogeneity was used to measure the proportion of total variation in study estimates due to heterogeneity rather than sampling error. If significant heterogeneity was found among studies based on interpretation of the

 I^2 test, a random effects model was applied. If no significant heterogeneity among studies was found, a fixed-effects model was applied. After this, the meta-analysis was carried out by using REVMAN software (version 5.0 for Windows. Copenhagen: The Nordic Cochrane Centre, the Cochrane Collaboration, 2008). *p* Values of less than 0.05 were considered statistically significant. We attempted to contact the original authors and inquire insufficient data of them. We also approached missing standard deviations for changes from the baseline by referring to Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 (16.1.3.2).

Results

Search strategy

We found 864 potentially eligible articles of which 12 studies were included [7–10, 12, 13, 15, 16, 19–21, 25, 31] (Fig. 1). A total of 841 patients were included, 469 of which received PFD and the other 175 adopted PFDD. The follow-up periods were more than 6 months (Table 1).

Outcome measure

Mean operative time

There studies [15, 16, 21] recorded the mean operative time. A meta-analysis showed there is significant difference in the operative time [mean difference = -74.63, 95 % CI (-83.02, -66.25), p < 0.05] (Fig. 2).

Complications

Twelve studies [7-10, 12, 13, 15, 16, 19-21, 25, 31] recorded the complications including neurological complications, CSF leak, wound infection, pseudomeningocele, and aseptic meningitis. There is significant difference in the complications between the two groups in favor of PFD [mean difference = 0.34, 95 % CI (0.19, 0.60), p < 0.05]. There is significant difference in the rate of CSF leak between the two groups [mean difference = 0.24, 95 % CI (0.07, 0.78), p < 0.05]. On the other hand, there is no significant difference between the two groups in the occurrence rate of neurological complications [mean difference = 0.25, 95 % CI (0.06, 1.10), p > 0.05], pseudomeningocele [mean difference=0.25, 95 % CI (0.05, 1.21), p > 0.05], and aseptic meningitis [mean difference = 0.26, 95 % CI (0.05, 1.22), p > 0.05] and in the wound infection rate [mean difference = 0.86, 95 % CI (0.28, 2.68), p > 0.05] (Figs. 3 and 4).



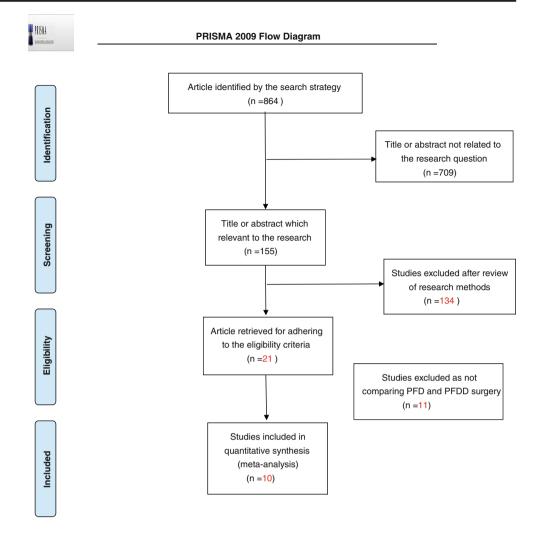


 Table 1
 General condition of the 12 studies included in the meta-analysis

Paper	Operation		Mean age		Gender (M/F)		Follow-up		Outcomes	
	PFD	PFDD	PFD	PFDD	PFD	PFDD	PFD	PFDD		
Chotai 2014	29	12	33.8 years	8/34 1.2 y		1.2 ye	ars	Clinical improvement, complications		
Erdogan 2010	12	15	31.58 years	25.86 years	9/3	15/0	NA		Clinical improvement, complications	
Galarza 2007	20	21	10 years	NA	1.8 years		ars	Clinical and imaging improvement, complications		
Gurbuz 2015	18	21	36 years		13/26		3.6 years		Complications	
Lee 2014	29	36	8.9 years			OR time, imaging improvement, complications				
Limonadi 2004	12	12	7.6 years	10.8 years	5/7 6/6		1.3y		OR time, complications	
MutchnIck 2010	56	64	11.1 years		58/63		0.5 years		OR time, complications	
Yilmaz 2011	24	58	38.9 years	31 years	36/46		0.8y		Clinical and imaging improvement, complications	
Romero 2010	6	10	40.6 years		6/10		1.4 years		Clinical improvement, complications	
McGrit 2007	116	140	29 ± 15 months		121/135		NA		Complications	
Munchi 2000	11	23	32.5 years		11/23		1–6 months		Clinical improvement, complications	
Hayhurst 2008	84	12	33.0 years	35/61 6 r		6 mon	ths-9 years	Clinical improvement, complications		

	PFD			PFDD				Mean Difference	Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV. Random, 95% Cl	IV, Random, 95% Cl
Lee 2014	90	24	29	168	42	36	26.6%	-78.00 [-94.26, -61.74]	
Limonadi 2004	99	24.5	12	169	38	12	10.7%	-70.00 [-95.58, -44.42]	
Mutchnick 2010	127	25	56	201	34	64	62.7%	-74.00 [-84.60, -63.40]	- -
Total (95% CI)			97			112	100.0%	-74.63 [-83.02, -66.25]	•
Heterogeneity: Tau ² = 0.00; Chi ² = 0.30, df = 2 (P = 0.86); $ ^2 = 0\%$ -100 -50 0 50 100									
Test for overall effect: $Z = 17.44$ (P < 0.00001)									PFD PFDD

Fig. 2 A meta-analysis showed there is significant difference of the operative time [mean difference = -74.63, 95 % CI (-83.02, -66.25), p < 0.05]

Fig. 3 There is significant difference in the complications between the two groups in favor of PFD [mean difference = 0.41, 95 % CI (0.30, 0.57), *p* < 0.05]. Specifically speaking, the occurrence rates of neurological complications [mean difference = 0.27, 95 % CI (0.07, 0.96), p < 0.05], CSF leak [mean difference = 0.16, 95 % CI (0.05, 0.51), p < 0.05],pseudomeningocele [mean difference = 0.10, 95 % CI (0.02, 0.53), *p* < 0.05], and aseptic meningitis [mean difference = 0.21, 95 % CI (0.05, 0.88), p < 0.05] are all significantly higher in the PFDD group compared to the PFD group. However, there is no significant difference in the wound infection rate between the two groups [mean difference = 0.86, 95 % CI (0.28, 2.68), p > 0.05]

$ \begin{array}{c c c c c c c c c c c c c c c c c c c $		PFD	PFDE)		Odds Ratio	Odds Ratio
6.1.1 Neurological complications Cholai 2014 0 23 4 12 13.6% 0.03 [0.00, 0.66] Romeno 2010 0 6 1 10 2.4% 0.48 [0.02, 13.92] Yilmaz 2011 1 2.4 58 2.5% 1.22 [0.11, 14.92] Total events 1 7 7 122 [0.11, 14.95] 0.25 [0.06, 1.10] Total events 1 7 7 0.25 [0.06, 1.10] 10 Cholai 2014 0 29 1 12 4.5% 0.21 [0.01, 4.35] Heterogeneity, Chi ² = 3.54, df = 2 (P = 0.17); P = 4.3% Testor overall effect Z = 1.83 (P = 0.07) 0.21 [0.01, 4.35] Cholai 2014 0 29 1 12 4.5% 0.21 [0.01, 4.35] Gurbuz 2015 1 18 2.4 0.38 [0.02, 6.85] 0.37 [0.02, 8.45] Subtotal (95% Cl) 129 17 3.2% 0.24 [0.07, 0.78] 0.38 [0.02, 6.85] Curbuz 2015 1 14 12 3.5% 0.38 [0.02, 6.85] 0.38 [0.02, 6.85] Curbuz 2015 1.8 1.8 1.2 3.6%	Study or Subgroup				Weight		
Cholai 2014 0 29 4 12 13.6% 0.03 [0.00, 0.66] Fromero 2010 0 6 1 10 2.4% 0.48 [0.02, 13.00, 0.46] Subtotal (95% CI) 59 7 Heterogenely, Chi ² 3.54, of = 2 (P = 0.17); P = 43% Trast are versel affect. Z = 1.83 (P = 0.17); P = 43% Erdogan 2010 0 12 2 15 4.8% Cholai 2014 0 29 1 12 4.5% 0.22 [0.01, 4.56] Gurbuz 2015 0 18 2 21 5.0% 0.21 [0.01, 4.69] Lee 2014 0 29 4 35 8.8% 0.22 [0.01, 4.56] Gurbuz 2015 0 18 2 21 5.0% 0.21 [0.01, 4.69] Lee 2014 0 29 4 35 8.8% 0.22 [0.01, 4.56] Gurbuz 2015 0 18 2 21 5.0% 0.21 [0.01, 2.68] Total events 0 14 Heterogenely, Chi ² = 0.77, df = 6 (P = 0.99); P = 0% Test for overall effect Z = 2.37 (P = 0.02) 6.1.3 Wound infection Cholai 2014 1 29 1 12 3.0% 0.39 [0.02, 6.85] Gurbuz 2015 0 18 1 12 3.0% 0.39 [0.02, 6.85] Gurbuz 2015 0 18 1 12 3.0% 0.39 [0.02, 6.85] Gurbuz 2015 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 0 36 0.9% 3.84 [0.15, 97.30] Romero 2010 1 6 1 10 1.4% Heterogenely, Chi ² = 0.77, df = 6 (P = 0.99); P = 0% Test for overall effect Z = 2.37 (P = 0.02) 6.1.3 Wound infection Cholai 2014 1 29 0 36 0.9% 3.84 [0.15, 97.30] Romero 2010 1 6 1 10 1.4% Unimaz 2011 1 24 1 58 1.2% 2.48 [0.15, 97.30] Romero 2010 1 6 1 10 1.4% Heterogenely, Chi ² = 0.08, df = 3 (P = 0.99); P = 0% Test for overall effect Z = 0.26 (P = 0.99); P = 0% Test for overall effect Z = 1.72 (P = 0.09); P = 0% Test for overall effect Z = 1.72 (P = 0.99); P = 0% Test for overall effect Z = 1.71 (P = 0.09) Fotal events 0 8 116 2.140 5.0% 0.24 [0.01, 3.27] Unimaz 2011 0 2.4 1 58 1.9% 0.25 [0.05, 1.21] 5.15 Aseptic meinglits Lee 2014 0 29 3 3 66 6.8% 0.16 [0.01, 3.27] Unimoval 2004 0 12 1 12 2.2% 0.31 [0.01, 8.2] 7.7 Heterogenely, Chi ² = 0.63, df = 3 (P = 0.89); P = 0% Test for overall effect Z = 1.71 (P = 0.09) Fotal events 0 0 8 43 100 0% Total events 0 0 8 43 100 0% 5.15 Aseptic meinglits Lee 2014 0 29 3 3 66 6.8% 0.16 [0.01, 3.27] Diale vents 0 0 8 Heterogenely, Chi ² = 0.63, df = 3 (P = 0.89); P = 0% Test for overall effect Z = 1.71 (
Remero 2010 0 6 1 10 2.4% 0.48 [0.02, 13.22] Yilmaz 2011 1 24 2 58 2.5% 1.22 [0.11, 4.08] Subtotal (95% C1) 59 80 18.5% 0.25 [0.06, 1.00] Total events 1 7 Total events 1 7 Heterogeneity. Chi ² 3.54, df = 2 (P = 0, 17); P = 4.3% Test for overall effect $Z = 1.83 (P = 0.07)$ 6.1.2 CSF leak Chotal 2014 0 29 1 12 4.5% 0.13 [0.00, 3.43] Erdogan 2010 0 12 2 15 4.8% 0.22 [0.01, 4.95] Gurbuz 2015 0 18 2 21 5.0% 0.21 [0.01, 4.95] Gurbuz 2015 0 18 2 23 3.5% 0.22 [0.01, 4.95] Heterogeneity. Chi ² = 0.77, df = 6 (P = 0.98); P = 0% Test for overall effect $Z = 2.37 (P = 0.02)$ 6.1.3 Wound infection Chotal 2014 1 29 175 32.2% 0.24 [0.07, 0.78] Total events 5 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 0.02 (1.3, 9.47] Total events 5 7 Heterogeneity. Chi ² = 0.17, df = 6 (P = 0.98); P = 0% Test for overall effect $Z = 1.02 (P = 0.78)$ 6.1.4 Pseudomeningotel Gurbuz 2015 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 0.6 0.9% 0.34 [0.10, 9.5342] Yilmaz 2011 1 24 158 12% 2.48 [0.15, 41.37] Subtotal (95% C1) 106 137 14.3% 0.36 [0.28, 2.68] Total events 5 7 Heterogeneity. Chi ² = 0.01, df = 4 (P = 0.56); P = 0% Test for overall effect $Z = 1.02 (P = 0.79)$ 6.1.4 Pseudomeningotel Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] McGit 2008 0 116 2 140 5.0% 0.37 [0.02, 8.46] Mutshnick 2010 0 56 2 64 51% 0.22 [0.01, 4.71] Subtotal (95% C1) 106 137 14.3% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity. Chi ² = 0.08, df = 3 (P = 0.99); P = 0% Test for overall effect $Z = 1.70 (P = 0.89); P = 0%$ Test for overall effect $Z = 1.71 (P = 0.09)$ 6.1.5 Aseptic meingitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Vilmaz 2010 0 6 3 10 5.6% 0.37 [0.02, 8.06] 6.15 Aseptic meingitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.22] Vilmaz 2010 0 6 3 10 5.6% 0.37 [0.02, 8.06] 9 EVENT 0 = 0.83, df = 3 (P = 0.99); P = 0% Test for overall effect $Z = 1.71 (P = 0.09)$ Total (e5% C1) 566 747 100.0% 0.34 [0.19, 0.60] 9 EVENT 0 = 0.07 = 0.07, df = 2 (P = 0.98); P = 0% Test for overall effect $Z = 1.077, df = 2 $	-		94	12	13.6%	0.03 [0.00, 0.66]	·
Subtotal (95% C1) 59 80 18.5% 0.25 [0.06, 1.10] Total events 1 7 Teterogeneity: $Ch^{P} = 3.64$, $df = 2 (P = 0.17)$; $P = 43%$ Test for overall effect $Z = 1.83 (P = 0.07)$ 6.1.2 CSF leak Chotal 2014 0 29 1 12 4.5% 0.13 [0.00, 3.43] Erdogan 2010 0 12 2 15 4.8% 0.22 [0.01, 4.69] Gurbuz 2015 0 18 2 21 5.0% 0.21 [0.01, 2.37] Munshi 2010 0 11 2 23 3.5% 0.37 [10.02, 8.46] Romero 2010 0 6 1 10 2.4% 0.49 [10.02, 13.92] Vilmaz 2011 0 24 25 83 2.2% 0.48 [10.02, 9.97] Subtotal (95% C1) 129 175 32.2% 0.48 [0.02, 13.92] Total events 0 0 14 Heterogeneity: $Ch^{P} = 0.77$, $df = 6 (P = 0.99)$; $P = 0%$ Test for overall effect $Z = 37 (P = 0.02)$ 6.1.3 Wound infection Chotal 2014 1 29 0.02 6.1.3 Wound infection Chotal 2015 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 0.02 6.1.3 Wound infection Chotal 2015 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 0.02 6.1.4 Pseudomeningocele Gurbuz 2015 1 18 1 12 3.0% 0.21 [0.01, 5.53] Total events 5 5 7 14.3% 0.86 [0.28, 2.68] Total events 0 7 Heterogeneity: $Ch^{P} = 0.03$, $df = 4 (P = 0.56)$; $P = 0\%$ Test for overall effect $Z = 0.26 (P = 0.99)$; $P = 0\%$ Test for overall effect $Z = 0.26 (P = 0.99)$; $P = 0\%$ Test for overall effect $Z = 0.26 (P = 0.99)$; $P = 0\%$ Test for overall effect $Z = 0.26 (P = 0.99)$; $P = 0\%$ Test for overall effect $Z = 1.72 (P = 0.09)$; $P = 0\%$ Test for overall effect $Z = 1.72 (P = 0.09)$; $P = 0\%$ Test for overall effect $Z = 1.72 (P = 0.09)$; $P = 0\%$ Test for overall effect $Z = 1.72 (P = 0.99)$; $P = 0\%$ Test for overall effect $Z = 1.71 (P = 0.09)$; $P = 0\%$ Test for overall effect $Z = 1.71 (P = 0.09)$; $P = 0\%$ Test for overall effect $Z = 1.71 (P = 0.09)$; $P = 0\%$ Test for overall effect $Z = 1.71 (P = 0.09)$; $P = 0\%$ Test for overall effect $Z = 1.71 (P = 0.09)$; $P = 0\%$ Test for overall effect $Z = 1.71 (P = 0.09)$; $P = 0\%$ Test for overall effect $Z = 10.77$, $df = 2 (P = 0.89)$; $P = 0\%$ Test for overall effect $Z = 10.77$, $df = 2 (P = 0.89)$; $P = 0\%$ Test for overall effect $Z = 10.77$	Romero 2010	0	61	10	2.4%		
Subtotal (95% (C) 59 80 18.5% 0.25 [0.06, 1.10] Total events 1 7 Heterogeneity: $Ch^{F} = 3.54$, $df = 2$ ($P = 0.17$); $P = 4.3\%$ Test for overall effect $Z = 1.83$ ($P = 0.07$) 6.1.2 CSF leak Chotai 2014 0 29 1 12 4.5% 0.13 [0.00, 3.43] Erdogan 2010 0 12 2 15 4.8% 0.22 [0.01, 4.69] Gurbuz 2015 0 18 2 21 5.0% 0.21 [0.01, 2.37] Munshi 2010 0 14 22 3 3.5% 0.37 [10.02, 8.46] Romero 2010 0 6 1 10 2.4% 0.49 [10.02, 13.92] Vilmaz 2011 0 24 25 8 3.2% 0.46 [10.02, 9.97] Subtotal (95% (C) 129 175 32.2% 0.48 [10.02, 9.97] Total events 0 0 14 Heterogeneity: $Ch^{F} = 0.77$, $df = 6$ ($P = 0.99$); $P = 0\%$ Test for overall effect $Z = 3.7$ ($P = 0.02$) 6.1.3 Wound infection Chotai 2014 1 29 0.25 (0.05, 14.21) Chotai 2015 1 18 4 21 7.7% 0.26 [0.02, 2.47] Lee 2014 1 29 0.023 6.1.3 Wound infection Chotai 2016 1 6 1 10 1.4% 180 [0.09, 35.42] Vilmaz 2015 1 18 4 21 7.7% 0.26 [0.02, 2.47] Lee 2014 1 29 0.023 6.1.4 Pseudomeningocle Gurbuz 2015 0 18 1 12 3.0% 0.21 [0.01, 5.53] Total events 0 7 Heterogeneity: $Ch^{F} = 0.27$ ($P = 0.99$); $P = 0\%$ Test for overall effect $Z = 0.26$ ($P = 0.99$); $P = 0\%$ Test for overall effect $Z = 0.26$ ($P = 0.99$); $P = 0\%$ Test for overall effect $Z = 0.26$ ($P = 0.99$); $P = 0\%$ Test for overall effect $Z = 0.26$ ($P = 0.99$); $P = 0\%$ Test for overall effect $Z = 1.72$ ($P = 0.09$); $P = 0\%$ Test for overall effect $Z = 1.72$ ($P = 0.09$); $P = 0\%$ Test for overall effect $Z = 1.72$ ($P = 0.09$); $P = 0\%$ Test for overall effect $Z = 1.72$ ($P = 0.09$); $P = 0\%$ Test for overall effect $Z = 1.72$ ($P = 0.09$); $P = 0\%$ Test for overall effect $Z = 1.71$ ($P = 0.09$); $P = 0\%$ Test for overall effect $Z = 1.71$ ($P = 0.09$); $P = 0\%$ Test for overall effect $Z = 1.71$ ($P = 0.09$); $P = 0\%$ Test for overall effect $Z = 1.71$ ($P = 0.09$); $P = 0\%$ Test for overall effect $Z = 1.71$ ($P = 0.09$); $P = 0\%$ Test for overall effect $Z = 1.71$ ($P = 0.09$); $P = 0\%$ Test for overall effect $Z = 0.77$ ($D = 20$); $P = 0\%$ Total (95% CI) 566 747 100.	Yilmaz 2011	1 2	4 2	58			
Total events 1 7 Heterogeneity: Ch ² = 3.4 ($l = 2(P = 0.17)$; P = 4.3% Test for overall effect Z = 1.83 (P = 0.07) 6.1.2 CSF leak Chotal 2014 0 29 1 12 4.5% 0.13 [0.00, 3.43] Erdogan 2010 0 12 2 15 4.8% 0.22 [0.01, 4.69] Gurbuz 2015 0 18 2 21 5.0% 0.21 [0.01, 4.69] Murshi 2010 0 11 2 23 3.5% 0.37 [0.02, 8.46] Normero 2010 0 6 1 10 2.4% 0.49 [0.02, 9.97] Subtotal (65% CI) 129 175 32.2% 0.24 [0.07, 0.78] Total events 0 14 Heterogeneity: Ch ² = 0.77, df = 6 (P = 0.99); f = 0% Test for overall effect Z = 2.37 (P = 0.02) 6.1.3 Wound infection Chotal 2014 1 29 1 12 3.0% 0.38 [0.02, 6.85] Gurbuz 2015 1 18 4 21 7.7% 0.25 [0.02, 2.47] Lee 2014 1 29 0 36 0.9% 3.84 [0.15, 97.90] Romero 2010 1 6 1 10 1.4% 1.80 [0.09, 35.42] Viimaz 2011 1 24 1 58 1.2% 2.48 [0.15, 97.90] Romero 2010 1 6 1 10 1.4% 1.80 [0.09, 35.42] Viimaz 2011 1 24 1 58 1.2% 0.24 [0.01, 5.53] Murshi 2016 0 116 2 140 5.0% 0.24 [0.01, 5.53] Heterogeneity: Ch ² = 0.26 (P = 0.99); F = 0% Test for overall effect Z = 0.26 (P = 0.99); F = 0% Test for overall effect Z = 1.72 (P = 0.09) 6.1.4 Pesudomeningocele Ourbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] Murshi 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Total events 0 7 Heterogeneity: Ch ² = 0.67 (-16 - 26 - 9); F = 0% Test for overall effect Z = 1.72 (P = 0.99); F = 0% Test for overall effect Z = 1.72 (P = 0.99); F = 0% Test for overall effect Z = 1.71 (P = 0.09) Total (95% CI) 74 116 17.2% 0.74 [0.00% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Ch ² = 0.63 (d = 3 (P = 0.89); F = 0% Test for overall effect Z = 1.71 (P = 0.09) Total (95% CI) 56 6 747 100.0% 0.34 [0.19, 0.60] Total (95% CI) 56 6 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Ch ² = 0.63 (P = 0.09); F = 0% Test for overall effect Z = 1.71 (P = 0.09) Total (95% CI) 56 6 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Ch ² = 0.63 (P = 0.09); F = 0% Test for overall effect Z = 0.72 (P = 0.99); F = 0% Test for overall effect Z = 0.72 (P = 0.99); F = 0% Test for overall e							
Test for overall effect: $Z = 1.83$ (P = 0.07) 6.1.2 CSF leak Chotal 2014 0 29 1 12 4.5% 0.13 [0.00, 3.43] Erdogan 2010 0 12 2 15 4.8% 0.22 [0.01, 4.85] Gurbuz 2015 0 18 2 21 5.0% 0.21 [0.01, 4.85] Murshi 2010 0 11 2 23 3.5% 0.37 [0.02, 8.46] Romero 2010 0 6 1 10 2.4% 0.44 [0.02, 9.97] Vimaz 2011 0 24 2 58 3.2% 0.46 [0.02, 9.97] Subtotal (65% C) 129 175 32.2% 0.24 [0.07, 0.78] Test for overall effect: Z = 2.37 (P = 0.09), I ⁺ = 0% Test for overall effect: Z = 2.37 (P = 0.09), I ⁺ = 0% Test for overall effect: Z = 0.26 (P = 0.99), I ⁺ = 0% Test for overall effect: Z = 0.26 (P = 0.09), I ⁺ = 0% Test for overall effect: Z = 0.26 (P = 0.09), I ⁺ = 0% Test for overall effect: Z = 0.26 (P = 0.09), I ⁺ = 0% Test for overall effect: Z = 0.26 (P = 0.09), I ⁺ = 0% Test for overall effect: Z = 0.26 (P = 0.09), I ⁺ = 0% Test for overall effect: Z = 0.26 (P = 0.09), I ⁺ = 0% Test for overall effect: Z = 1.72 (P = 0.09) 6.1.4 Pesudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] Michic 2008 0 116 2 140 5.0% 0.27 [0.01, 2.846] Murshi 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Test for overall effect: Z = 1.72 (P = 0.09) 6.1.4 Sequidomeningocele Gurbuz 2015 0 18 1 12 3.2% 0.31 [0.01, 5.53] Michic 2008 0 116 2 140 5.0% 0.37 [1.00, 2.846] Mutshic 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Test for overall effect: Z = 1.72 (P = 0.09) 6.1.5 Aseptic meningits Lee 2014 0 12 1 12 3.2% 0.31 [0.01, 8.31] Total events 0 7 Test for overall effect: Z = 1.72 (P = 0.09) 6.15 (0.05, 1.21] Total events 0 8 Heterogeneity: Ch ⁺ = 0.63, df = 3 (P = 0.89); I ⁺ = 0% Test for overall effect: Z = 1.71 (P = 0.09) Total (95% CI) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Ch ⁺ = 0.63, df = 3 (P = 0.89); I ⁺ = 0% Test for overall effect: Z = 1.71 (P = 0.09) Total events 6 43 Heterogeneity: Ch ⁺ = 0.63, df = 3 (P = 0.89); I ⁺ = 0% Test for overall effect: Z = 0.72 (P = 0.89); I ⁺ = 0% Test for overall effect: Z = 0.77, df = 22 (P = 0.89); I ⁺ = 0% Test for overall effect		1	7				
Test for overall effect: $Z = 1.83$ (P = 0.07) 6.1.2 CSF leak Chotal 2014 0 29 1 12 4.5% 0.13 (0.00, 3.43) Erdogan 2010 0 12 2 15 4.8% 0.22 (0.01, 4.95) Gurbuz 2015 0 18 2 21 5.0% 0.21 (0.01, 4.95) Murshi 2010 0 11 2 23 3.5% 0.37 (0.02, 8.46) Romero 2010 0 6 1 10 2.4% 0.48 (0.02, 9.97) Subtolal (95% C) 129 175 32.2% 0.24 (0.07, 0.78) Total events 0 14 Heterogeneity: Ch ² = 0.77, df = 6 (P = 0.99), P = 0% Test for overall effect: Z = 2.37 (P = 0.09), P = 0% Test for overall effect: Z = 2.37 (P = 0.09), P = 0% Test for overall effect: Z = 2.37 (P = 0.09), P = 0% Total events 0 14 Heterogeneity: Ch ² = 3.01, df = 4 (P = 0.56), P = 0.0% Test for overall effect: Z = 0.26 (P = 0.56), P = 0.0% Test for overall effect: Z = 0.26 (P = 0.56), P = 0.0% Test for overall effect: Z = 0.26 (P = 0.56), P = 0.0% Test for overall effect: Z = 1.72 (P = 0.09) 6.1.4 Peeudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 (0.01, 5.53) Michit 2008 0 116 2 140 5.0% 0.23 (0.02, 8.46) Mutchnick 2010 0 56 2 64 5.1% 0.22 (0.01, 8.31) Murshi 2010 0 11 2 23 3.5% 0.37 (1002, 8.46) Mutchnick 2010 0 56 2 64 5.1% 0.22 (0.01, 8.31) Mutchick 2010 0 56 2 64 5.1% 0.22 (0.01, 8.31) Mutchick 2010 0 56 2 64 5.1% 0.22 (0.01, 8.31) Mutchick 2010 0 56 2 64 5.1% 0.22 (0.01, 8.31) Mutchick 2010 0 56 2 64 5.1% 0.22 (0.01, 8.31) Mutchick 2010 0 56 2 64 5.1% 0.22 (0.01, 8.31) Mutchick 2010 0 56 2 64 5.1% 0.22 (0.01, 8.31) Mutchick 2010 0 58 2 64 5.1% 0.22 (0.01, 8.31) Mutchick 2010 0 58 2 64 5.1% 0.22 (0.01, 8.31) Mutchick 2010 0 58 2 64 5.1% 0.22 (0.01, 8.31) Total events 0 7 Heterogeneity: Ch ² = 0.63, df = 3 (P = 0.89); P = 0% Test for overall effect: Z = 1.72 (P = 0.09) Total (95% CI) 77 1 116 17.5% 0.26 (0.05, 1.22) Total events 6 43 Heterogeneity: Ch ² = 0.63, df = 3 (P = 0.89); P = 0% Test for overall effect: Z = 1.71 (P = 0.09) Total (95% CI) 56 747 100.0% 0.34 (0.19, 0.60) Total events 6 43 Heterogeneity: Ch ² = 0.63, df = 3 (P = 0.89); P = 0% Test for overall effect: Z = 0.72 (P = 0.89); P = 0% Test for ov		3.54, df = 2 (P	= 0.17); l ² =	43%			
Chobai 2014 0 29 1 12 45% 013 [0 00, 34] Erdogan 2010 0 12 2 15 48% 0.22 [0.01, 4.95] Gurbuz 2015 0 18 2 21 50% 0.27 [0.01, 4.37] Lee 2014 0 29 4 36 8.8% 0.12 [0.01, 2.37] Wunshi 2010 0 6 1 10 2.4% 0.49 [0.02, 13.92] Yilmaz 2011 0 24 2 58 3.2% 0.46 [0.02, 9.97] Yilmaz 2011 0 24 2 58 3.2% 0.46 [0.02, 9.97] Yilmaz 2011 0 24 2 58 3.2% 0.46 [0.02, 9.97] Total events 0 14 Heterogeneity Ch ² = 0.77, df = 67 (e 0.99); $F = 0\%$ Test for overall effect: $Z = 0.23$ ($F = 0.89$); $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.59)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.59)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 1.72 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.72 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.72 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.72 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.71 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.71 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.71 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.71 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.71 (P = 0.09)$; $F = 0\%$		• •					
Chobai 2014 0 29 1 12 45% 013 [0 00, 34] Erdogan 2010 0 12 2 15 48% 0.22 [0.01, 4.95] Gurbuz 2015 0 18 2 21 50% 0.27 [0.01, 4.37] Lee 2014 0 29 4 36 8.8% 0.12 [0.01, 2.37] Wunshi 2010 0 6 1 10 2.4% 0.49 [0.02, 13.92] Yilmaz 2011 0 24 2 58 3.2% 0.46 [0.02, 9.97] Yilmaz 2011 0 24 2 58 3.2% 0.46 [0.02, 9.97] Yilmaz 2011 0 24 2 58 3.2% 0.46 [0.02, 9.97] Total events 0 14 Heterogeneity Ch ² = 0.77, df = 67 (e 0.99); $F = 0\%$ Test for overall effect: $Z = 0.23$ ($F = 0.89$); $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.59)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.59)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.99)$; $F = 0\%$ Test for overall effect: $Z = 1.72 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.72 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.72 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.72 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.71 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.71 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.71 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.71 (P = 0.09)$; $F = 0\%$ Test for overall effect: $Z = 1.71 (P = 0.09)$; $F = 0\%$	612CSE loak						
Erdogan 2010 0 12 2 15 48% 022 [001, 453] Gurbuz 2015 0 18 2 21 50% 0.21 [0.01, 4.69] Mushi 2010 0 11 2 23 3.5% 0.37 [0.02, 8.46] Romero 2010 0 6 1 10 2.4% 0.49 [0.02, 13.92] Yilmaz 2011 0 24 2 58 3.2% 0.46 [0.02, 9.97] Subtotal (95% C) 129 175 32.2% 0.24 [0.07, 0.78] Total events 0 14 Heterogeneity: Ch ² = 0.77, df = 6 (P = 0.99); P = 0% Test for overall effect Z = 0.37 (P = 0.02) 6.1.3 Wound infection Chotal 2014 1 29 1 12 3.0% 0.39 [0.02, 8.85] Gurbuz 2015 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 0 36 0.9% 3.84 [0.15, 97.90] Romero 2010 1 6 1 10 1.4% 1.80 [0.09, 35.42] Yilmaz 2011 1 24 1 58 1.2% 2.48 [0.15, 41.32] Subtotal (95% C) 106 137 14.3% 0.86 [0.28, 2.68] Total events 5 7 Heterogeneity: Ch ² = 3.01, df = 4 (P = 0.56); P = 0% Test for overall effect Z = 0.28 (P = 0.79) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 33% 0.21 [0.01, 5.53] Mushnick 2010 0 56 2 64 5.1% 0.22 [0.05, 1.21] Total events 0 7 Heterogeneity: Ch ² = 0.08, df = 3 (P = 0.99); P = 0% Test for overall effect Z = 1.72 (P = 0.09); P = 0% Test for overall effect Z = 1.72 (P = 0.09); P = 0% Test for overall effect Z = 1.72 (P = 0.09); P = 0% Test for overall effect Z = 1.71 (P = 0.09); P = 0% Test for overall effect Z = 1.71 (P = 0.09); P = 0% Test for overall effect Z = 1.71 (P = 0.09); P = 0% Test for overall effect Z = 1.71 (P = 0.09); P = 0% Test for overall effect Z = 1.71 (P = 0.09); P = 0% Test for overall effect Z = 1.71 (P = 0.09); P = 0% Test for overall effect Z = 1.71 (P = 0.09); P = 0% Test for overall effect Z = 1.71 (P = 0.09); P = 0% Test for overall effect Z = 1.71 (P = 0.09); P = 0% Test for overall effect Z = 1.71 (P = 0.09); P = 0% Test for overall effect Z = 0.72 (P = 0.09); P = 0% Test for overall effect Z = 0.72 (P = 0.09); P = 0% Test for overall effect Z = 0.72 (P = 0.09); P = 0% Test for overall effect Z = 0.72 (P = 0.09); P = 0%		0 0	0 1	10	1 501	0 4 3 10 00 3 4 31	
Gurbur 2015 0 18 2 21 5.0% 0.21 0.01 4.891 Lee 2014 0 29 4 36 8.8% 0.12 0.01, 2.871 Munshi 2010 0 11 2 23 55% 0.37 [0.02, 8.46] Romero 2010 0 6 1 10 2.4% 0.48 [0.02, 9.37] Subtotal (95% CI) 129 175 32.2% 0.48 [0.02, 9.37] Total events 0 14 29 1.22 30% 0.39 [0.02, 6.85] Gurbuz 2015 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 1 12 30% 0.39 [0.02, 6.85] Gurbuz 2015 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 6 1.01 1.4% 1.80 [0.60, 3.54.2] Yilmaz 2011 1 2.4 1.6 5.7 7 Heterogeneity: Chi ^P = 3.01, df = 4 (P = 0.56); P = 0.% 7							
Lee 2014 0 29 4 36 8 8% 0.12 [0.01, 2.37] Munshi 2010 0 11 2 23 3.5% 0.37 [0.02, 8.46] Romero 2010 0 6 1 10 2.4% 0.49 [0.02, 13.32] Yilmaz 2011 0 24 2 56 3.2% 0.46 [0.02, 9.97] Total events 0 14 Heterogeneity: Chi ² = 0.77, df = 6 (P = 0.99); P = 0% Test for overall effect: Z = 2.37 (P = 0.02) 6.1.3 Wound infection Chotai 2014 1 29 1 12 3.0% 0.39 [0.02, 6.85] Gurbuz 2015 1 18 4 221 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 0 36 0.9% 3.34 (0.15, 97.30] Romero 2010 1 6 1 10 1.4% 1.80 [0.09, 35.42] Yilmaz 2011 1 24 1 58 1.2% 2.48 [0.15, 41.32] Subtotal (95% Cl) 106 137 14.3% 0.26 [0.02, 8.26] Fest for overall effect: Z = 0.26 (P = 0.99); P = 0% Test for overall effect: Z = 0.26 (P = 0.79) 6.1.4 Pseudomeningocele Gurbuz 2015 0 118 1 12 3.8% 0.21 [0.01, 5.53] Munshi 2010 0 112 2 23 3.5% 0.37 [0.02, 8.46] Mutchnick 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% Cl) 201 223 3.5% 0.37 [0.02, 8.46] Mutchnick 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% Cl) 201 223 3.66 6.8% 0.16 [0.01, 3.27] Heterogeneity: Chi ² = 0.6] df = 9 (P = 0.99); P = 0% Test for overall effect: Z = 1.72 (P = 0.99); P = 0% Test for overall effect: Z = 1.72 (P = 0.99); P = 0% Test for overall effect: Z = 1.72 (P = 0.99); P = 0% Test for overall effect: Z = 1.72 (P = 0.99); P = 0% Test for overall effect: Z = 1.72 (P = 0.99); P = 0% Test for overall effect: Z = 1.71 (P = 0.09) Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] PED PEDD						• • •	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$							L
Romero 2010 0 6 1 10 2.4% 0.49 [0.02, 13.92] Yilmaz 2011 0 2.4 2 58 3.2% 0.46 [0.02, 9.97] Subtotal (95% Cl) 129 175 32.2% 0.24 [0.07, 0.78] Total events 0 14 Heterogeneity: Chi ² = 0.7, df = 6 (P = 0.99); P = 0% Test for overall effect Z = 2.37 (P = 0.02) 6.1.3 Wound infection Choiai 2014 1 29 0.36 0.9% 3.84 [0.15, 97.30] Gurbuz 2015 1 18 4 21 7.7% 0.25 [0.03, 2.47] Yilmaz 2011 1 24 1.58 0.27 [0.03, 54.2] Yilmaz 2011 1 24 1.58 0.24 [0.01, 5.53] Total events 5 7 7 Heterogeneity: Chi ² = 3.01, df = 4 (P = 0.56); P = 0% Test for overall effect Z = 0.26 (P = 0.79) 6.1.4 Pseudomeningocele 0.21 [0.01, 5.53] 0.22 [0.01, 4.71] Gurbus 2015 0 18 1.2 3.8% 0.21 [0.01, 5.53] Mutchnick 2010 0 56 2.64 51% 0.22 [0.01, 4.71]							
Yilmaz 2011 0 24 2 58 3.2% 0.46 0.10, 2, 9.97 Subtotal (95% CI) 129 175 32.2% 0.24 0.02, 0.78 Total events 0 14 Heterogeneity: $Ch^{P} = 0.77$, $df = 6 (P = 0.99)$, $P = 0\%$ 7 0.24 0.02, 6.85 Gurbuz 2015 1 18 4 21 7.7% 0.25 0.03, 2.47 Lee 2014 1 29 0 36 0.9% 3.84 0.15, 97.90 Romero 2010 1 6 1.10 1.4% 1.80 0.25 0.26 0.39 0.24 0.15, 57.90 Yilmaz 2011 1 24 1 58 1.2% 2.48 10.15, 53 0.35 0.21 0.01 0.53 Subtotal (95% CI) 106 137 14.3% 0.86 0.24 0.01, 5.53 0.7 Heterogeneity: Chi ^P = 3.01, df = 4 (P = 0.56); I ^P = 0% 7 0.25 0.02, 0.14, 51 0.25 0.25 0.25 0.21 0.21, 0.01, 5.53 Mutchnick 2010 0 56 2 64							
Subtotal (95% CI) 129 175 32.2% 0.24 (0.07, 0.78] Total events 0 14 Heterogeneity: Ch ⁺ 0.7, df = 6 (P = 0.99); P = 0% Test for overall effect: $Z = 2.37$ (P = 0.02) 6.1.3 Wound infection Chotal 2014 1 29 1 12 3.0% 0.39 (0.02, 6.85) Gurbuz 2015 1 18 4 21 7.7% 0.25 (0.03, 2.47] Vilmaz 2011 1 24 1 58 1.2% 2.48 (0.15, 97.90) Romero 2010 1 6 1 10 1.4% 1.80 (0.09, 35.42) Vilmaz 2011 1 24 1 58 1.2% 2.48 (0.15, 41.32) Subtotal (95% CI) 106 137 14.3% 0.24 (0.01, 5.53) McGirl 2008 0 116 2 140 5.0% 0.24 (0.01, 5.53) McGirl 2008 0 116 2 140 5.0% 0.22 (0.01, 5.53) McGirl 2008 0 116 2 140 5.0% 0.22 (0.01, 5.64) Mutchnick 2010 0 56 2 64 5.1% 0.22 (0.01, 4.71) Subtotal (95% CI) 201 239 17.5% 0.25 (0.05, 1.21) Total events 0 7 Heterogeneity: Chi ⁺ = 0.08, df = 3 (P = 0.99); P = 0% Test for overall effect: $Z = 1.72$ (P = 0.99) 6.1.5 Aseptic meningitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Heterogeneity: Chi ⁺ = 0.08, df = 3 (P = 0.99); P = 0% Test for overall effect: $Z = 1.72$ (P = 0.99) Total events 0 7 Heterogeneity: Chi ⁺ = 0.8, df = 3 (P = 0.99); P = 0% Test for overall effect: $Z = 1.71$ (P = 0.99) Total events 0 $R = 3$ 19 5.6% 0.16 [0.01, 3.27] Total events 0 $R = 3$ 19 5.6% 0.37 [0.02, 1.83] Heterogeneity: Chi ⁺ = 0.63, df = 3 (P = 0.98); P = 0% Test for overall effect: $Z = 1.71$ (P = 0.09) Total (95% CI) 71 116 17.5% 0.26 [0.05, 1.22] Total events 6 $R = 3$ 19 % 0.34 [0.19, 0.60] Total events 6 $R = 3$ 19 % 0.34 [0.19, 0.60] Total events 6 $R = 3$ 19 % 0.34 [0.19, 0.60] Total (95% CI) 566 747 100.0% 0.34 [0.19, 0.60] R = D, PEDD							
Total events 0 14 Heterogeneity: Chi ^P = 0.77, df = 6 (P = 0.99); P = 0% Test for overall effect: $Z = 2.37$ (P = 0.02) 6.1.3 Wound infection Chotal 2014 1 29 1 12 3.0% 0.39 [0.02, 6.85] Gurbuz 2015 1 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 0 36 0.9% 3.84 [0.15, 97.90] Romero 2010 1 6 1 1 10 1.4% 1.80 [0.09, 35.42] Yilmaz 2011 1 24 1 58 1.2% 2.48 [0.15, 41.32] Subtotal (95% CI) 106 137 14.3% 0.86 [0.28, 2.68] Total events 5 7 Heterogeneity: Chi ^P = 3.01, df = 4 (P = 0.56); P = 0% Test for overall effect: $Z = 0.26$ (P = 0.79) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] Muchnick 2010 0 116 2 140 5.0% 0.24 [0.01, 5.00] Muschnick 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% CI) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ^P = 0.08, df = 3 (P = 0.99); P = 0% Test for overall effect: $Z = 1.72$ (P = 0.09) Total (95% CI) 71 116 17.5% 0.78 [0.03, 19.88] Heterogeneity: Chi ^P = 0.88, df = 3 (P = 0.99); P = 0% Test for overall effect: $Z = 1.71$ (P = 0.09) Total (95% CI) 71 116 17.5% 0.34 [0.19, 0.60] Total events 0 8 Heterogeneity: Chi ^P = 0.83, df = 3 (P = 0.98); P = 0% Test for overall effect: $Z = 1.71$ (P = 0.09) Total (95% CI) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 4 3 Heterogeneity: Chi ^P = 10.77, df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.77$ (df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.77$ (df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.77$ (df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.77$ (df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.77$ (df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.77$ (df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.77$ (df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.77$ (df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.77$ (df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.77$ (df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.77$ (df = 22 (
Heterogeneity: Chi ² = 0.77, df = 6 (P = 0.99); P = 0% Test for overall effect: $Z = 2.37$ (P = 0.02) 6.1.3 Wound infection Chotal 2014 1 29 1 12 3.0% 0.39 [0.02, 6.85] Gurbuz 2015 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 0 36 0.9% 3.84 [0.15, 97.90] Romero 2010 1 6 1 10 1.4% 1.80 [0.09, 35.42] Yilmaz 2011 1 24 1 5.8 1.2% 2.48 [0.15, 41.32] Subtotal (95% Cl) 106 137 14.3% 0.86 [0.28, 2.68] Total events 5 7 Heterogeneity: Chi ² = 3.01, df = 4 (P = 0.56); P = 0% Test for overall effect: $Z = 0.26$ (P = 0.79) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] MucSint 2008 0 116 2 140 5.0% 0.24 [0.01, 2.646] Mutchnick 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% Cl) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08, df = 3 (P = 0.99); P = 0% Test for overall effect: $Z = 1.72$ (P = 0.09) 6.1.5 Aseptic meningits Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.27] Vilmaz 2011 0 24 1 58 1.9% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.68, df = 3 (P = 0.89); P = 0% Test for overall effect: $Z = 1.71$ (P = 0.09) Total (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] Total events 6 4 3 Heterogeneity: Chi ² = 1.67, df = 2.2 (P = 0.99); P = 0% Test for overall effect: $Z = 1.77$ ($P = 0.93$); $P = 0\%$ Test for overall effect: $Z = 1.77$ ($P = 0.93$); $P = 0\%$ Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] PED PEDO				115	52.2 /0	0.24 [0.07, 0.70]	
Test for overall effect: $Z = 2.37$ ($P = 0.02$) 6.1.3 Wound infection Chotai 2014 1 29 1 12 3.0% 0.39 [0.02, 6.85] Gurbuz 2015 1 18 4 21 7.7% 0.25 [0.03, 247] Lee 2014 1 29 0 3 6 0.9% 3.84 [0.15, 97.00] Romero 2010 1 6 1 10 1.4% 1.80 [0.09, 35.42] Yilimaz 2011 1 24 1 58 1.2% 2.48 [0.15, 41.32] Subtotal (95% CI) 106 137 14.3% 0.86 [0.28, 2.68] Total events 5 7 Heterogeneity: Chi ² = 3.01, df = 4 (P = 0.56); P = 0% Test for overall effect: $Z = 0.26$ ($P = 0.79$) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] McGirt 2008 0 116 2 140 5.0% 0.24 [0.01, 5.00] Mutchnick 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% CI) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08; df = 3 (P = 0.99); P = 0% Test for overall effect: $Z = 1.72$ ($P = 0.09$) 6.1.5 Aseptic meningits Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Hitmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 18.8] Subtotal (95% CI) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); P = 0% Test for overall effect: $Z = 1.71$ ($P = 0.09$) Total (95% CI) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 4 3 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 1.71$ ($P = 0.09$) Total (95% CI) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 4 3 Heterogeneity: Chi ² = 1.62 (P = 0.99); P = 0% Test for overall effect: $Z = 1.71$ ($P = 0.09$) Total (95% CI) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 4 3 Heterogeneity: Chi ² = 1.62 (P = 0.093); P = 0% Test for overall effect: $Z = 1.71$ ($P = 0.09$) Total (95% CI) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 4 3 Heterogeneity: Chi ² = 1.62 (P = 0.093); P = 0% Test for overall effect: $Z = 3.66$ ($P = 0.903$); $P = 0$ %		-		0%			
Chotai 2014 1 29 1 12 3.0% 0.39 [0.02, 6.85] Gurbuz 2015 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 0 36 0.9% 3.84 [0.15, 97.90] Romero 2010 1 6 1 10 1.4% 1.80 [0.09, 35.42] Yilmaz 2011 1 24 1 58 1.2% 2.48 [0.15, 41.32] Subtotal (95% CI) 106 137 14.3% 0.86 [0.28, 2.68] Total events 5 7 Heterogeneity: Chi ² = 3.01, df = 4 ($P = 0.56$); $F = 0\%$ Test for overall effect $Z = 0.28$ ($P = 0.79$) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] McGirt 2008 0 116 2 140 5.0% 0.24 [0.01, 5.00] Munshi 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% CI) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08, df = 3 ($P = 0.99$); $F = 0\%$ Test for overall effect $Z = 1.72$ ($P = 0.99$); $F = 0\%$ Total events 0 7 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 6 4 43 Heterogeneity: Chi ² = 1.77, df = 22 ($P = 0.99$); $F = 0\%$ Total events 6 4 43 Heterogeneity: Chi ² = 1.77, df = 22 ($P = 0.99$); $F = 0\%$ Test for overall effect $Z = 3.66$ ($P = 0.0003$)				0,0			
Chotai 2014 1 29 1 12 3.0% 0.39 [0.02, 6.85] Gurbuz 2015 1 18 4 21 7.7% 0.25 [0.03, 2.47] Lee 2014 1 29 0 36 0.9% 3.84 [0.15, 97.90] Romero 2010 1 6 1 10 1.4% 1.80 [0.09, 35.42] Yilmaz 2011 1 24 1 58 1.2% 2.48 [0.15, 41.32] Subtotal (95% CI) 106 137 14.3% 0.86 [0.28, 2.68] Total events 5 7 Heterogeneity: Chi ² = 3.01, df = 4 ($P = 0.56$); $F = 0\%$ Test for overall effect $Z = 0.28$ ($P = 0.79$) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] McGirt 2008 0 116 2 140 5.0% 0.24 [0.01, 5.00] Munshi 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% CI) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08, df = 3 ($P = 0.99$); $F = 0\%$ Test for overall effect $Z = 1.72$ ($P = 0.99$); $F = 0\%$ Total events 0 7 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 ($P = 0.99$); $F = 0\%$ Total events 6 4 43 Heterogeneity: Chi ² = 1.77, df = 22 ($P = 0.99$); $F = 0\%$ Total events 6 4 43 Heterogeneity: Chi ² = 1.77, df = 22 ($P = 0.99$); $F = 0\%$ Test for overall effect $Z = 3.66$ ($P = 0.0003$)							
Gurbuz 2015 1 18 4 21 7.7% $0.25[0.03, 2.47]$ Lee 2014 1 29 0 36 0.9% $3.84[0.15, 97.90]$ Romero 2010 1 6 1 10 1.4% $1.80[0.09, 35.42]$ Yilmaz 2011 1 24 1 58 1.2% $2.48[0.15, 97.90]$ Total events 5 7 Heterogeneity. Chi ² = 3.01, df = 4 (P = 0.56), iP = 0% Test for overall effect. Z = 0.26 (P = 0.79) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 2 3.8% $0.21 [0.01, 5.53]$ Muchnick 2010 0 56 2 64 5.1% $0.22 [0.01, 4.71]$ Subtotal (95% cl) 201 239 3.5% $0.37 [0.02, 8.46]$ Mutchnick 2010 0 56 2 64 5.1% $0.22 [0.01, 4.71]$ Subtotal (95% cl) 201 239 3.66 6.8% $0.16 [0.01, 3.27]$ Heterogeneity. Chi ² = 0.08, df = 3 (P = 0.99); i ² = 0% $0.16 [0.01, 3.82]$ $0.78 [0.03, 19.88]$ $0.78 [0.03, 19.88]$. .				
Lee 2014 1 29 0 36 0.9% 3.84 [0.15, 97.90] Romero 2010 1 6 1 10 1.4% 1.80 [0.09, 35.42] Yilmaz 2011 1 24 1 58 1.2% 2.48 [0.15, 41.32] Subtotal (95% CI) 106 137 14.3% 0.86 [0.28, 2.68] Total events 5 7 Heterogeneity: Chi ² = 3.01, df = 4 (P = 0.56), P = 0% Test for overall effect Z = 0.26 (P = 0.79) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] McGirl 2008 0 116 2 140 5.0% 0.24 [0.01, 5.00] Muschi 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% CI) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08, df = 3 (P = 0.99); P = 0% Test for overall effect Z = 1.72 (P = 0.99) For the events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.99); P = 0% Test for overall effect Z = 1.71 (P = 0.09) Total (95% CI) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 4 3 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.99); P = 0% Test for overall effect Z = 1.71 (P = 0.09) Total (95% CI) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 4 3 Heterogeneity: Chi ² = 0.73, df = 22 (P = 0.98); P = 0% Test for overall effect Z = 3.66 (P = 0.0003) For the events 6 6 43 Heterogeneity: Chi ² = 0.73, df = 22 (P = 0.98); P = 0% Test for overall effect Z = 3.66 (P = 0.0003)						• • •	-
Romero 2010 1 6 1 10 1.4% 1.80 10.09, 35.42 Yilmaz 2011 1 24 1 58 1.2% 2.48 [0.15, 41.32] Subtotal (95% Cl) 106 137 14.3% 0.86 [0.28, 2.68] Total events 5 7 Heterogeneity: Chi ² = 3.01, df = 4 (P = 0.56); I ² = 0% Test for overall effect: $Z = 0.26$ (P = 0.79) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] McCint 2008 0 116 2 140 5.0% 0.24 [0.01, 4.71] Subtotal (95% Cl) 201 203 17.5% 0.25 [0.05, 1.21] Total events 0 7 7 Heterogeneity: Chi ² = 0.09, df = 3 (P = 0.99); I ² = 0% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.27] Limonadi 2004 0 12 12 3.2% 0.31 [0.01, 8.31] 7 Romero 2010 0 6 3 10 5.6% 0.26 [0.05,						• • •	-
Yilmaz 2011 1 24 1 58 1.2% 2.48 0.15 , 41.32 Subtotal (95% Cl) 106 137 14.3% 0.86 0.28 , 2.68 Total events 5 7 Heterogeneity: Chi [#] = 3.01, df = 4 (P = 0.56); I [#] = 0% Test for overall effect: $Z = 0.26$ (P = 0.79) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] McGirt 2008 0 116 2 140 5.0% 0.24 [0.01, 5.00] Mutchnick 2010 0 56 2.64 5.1% 0.22 [0.01, 4.71] Subtotal (95% Cl) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi [#] = 0.08, df = 3 (P = 0.99); I [#] = 0% 2.66 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 2 3.2% 0.31 [0.01, 8.31] Romero 2010 6 3 10 5.6% 0.16 [0.01, 3.27] 1116 17.5% 0.26 [0.05, 1.22] 101 10 101 Total events 0 <t< td=""><td></td><td></td><td></td><td></td><td></td><td>• • •</td><td></td></t<>						• • •	
Subtotal (95% Cl) 106 137 14.3% 0.86 [0.28, 2.68] Total events 5 7 Heterogeneity: Chi ² = 3.01, df = 4 (P = 0.56); I ² = 0% Test for overall effect: $Z = 0.26$ (P = 0.79) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] Mushi 2010 0 11 2 23 3.5% 0.37 [0.02, 8.46] Muthnick 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% Cl) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08, df = 3 (P = 0.99); I ² = 0% Test for overall effect: $Z = 1.72$ (P = 0.09) 6.1.5 Aseptic meningitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.22] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); I ² = 0% Test for overall effect: $Z = 1.71$ ($P = 0.09$) Total events 6 43 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); I ² = 0% Test for overall effect: $Z = 1.71$ ($P = 0.98$); I ² = 0% Test for overall effect: $Z = 1.71$ ($P = 0.98$); I ² = 0% Test for overall effect: $Z = 3.66$ ($P = 0.080$); I ² = 0% Test for overall effect: $Z = 3.66$ ($P = 0.080$); I ² = 0% Test for overall effect: $Z = 3.66$ ($P = 0.080$); I ² = 0% Test for overall effect: $Z = 3.66$ ($P = 0.080$); I ² = 0% Test for overall effect: $Z = 3.66$ ($P = 0.080$); I ² = 0% Test for overall effect: $Z = 3.66$ ($P = 0.080$); I ² = 0%							
Total events 5 7 Heterogeneity: $Chi^{2} = 3.01, df = 4 (P = 0.56); P = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.79)$ 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] McGirt 2008 0 116 2 140 5.0% 0.24 [0.01, 5.00] Munshi 2010 0 11 2 23 3.5% 0.37 [0.02, 8.46] Mutchnick 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% Cl) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08, df = 3 (P = 0.99); P = 0% Test for overall effect: $Z = 1.72 (P = 0.09)$ 6.1.5 Aseptic meningitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.82] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.99); P = 0% Test for overall effect: $Z = 1.71 (P = 0.09)$ Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Chi ² = 1.0.77, df = 22 (P = 0.98); P = 0% Test for overall effect: $Z = 3.66 (P = 0.0003)$						• • •	
Heterogeneity: $Chi^2 = 3.01, df = 4 (P = 0.56); h^2 = 0\%$ Test for overall effect: $Z = 0.26 (P = 0.79)$ 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] McGirt 2008 0 116 2 140 5.0% 0.24 [0.01, 5.00] Munshi 2010 0 11 2 23 3.5% 0.37 [0.02, 8.46] Mutchnick 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% CI) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08, df = 3 (P = 0.99); h ² = 0% Test for overall effect: $Z = 1.72 (P = 0.09)$ 6.1.5 Aseptic meningitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.22] Vilmaz 2011 0 24 1 58 1.9% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); h ² = 0% Test for overall effect: $Z = 1.71 (P = 0.09)$ Total events 6 43 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.98); h ² = 0% Test for overall effect: $Z = 1.77 (P = 0.98); h2 = 0\%$ Total (95% CI) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); h ² = 0% Test for overall effect: $Z = 3.66 (P = 0.0003)$				137	14.3%	0.86 [0.28, 2.68]	
Test for overall effect: $Z = 0.26$ (P = 0.79) 6.1.4 Pseudomeningocele Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] McGirt 2008 0 116 2 140 5.0% 0.24 [0.01, 5.00] Munshi 2010 0 11 2 23 3.5% 0.37 [0.02, 8.46] Mutchnlck 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% Cl) 201 239 17.5% 0.25 [0.05, 1.21] 10 Total events 0 7 12 3.2% 0.31 [0.01, 3.27] 10 Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] 10 Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.27] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] 10 Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] 10 10		-	•	~~			
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$				0%			
Gurbuz 2015 0 18 1 12 3.8% 0.21 [0.01, 5.53] McGirt 2008 0 116 2 140 5.0% 0.24 [0.01, 5.00] Munshi 2010 0 11 2 23 3.5% 0.37 [0.02, 8.46] Mutchnick 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% Cl) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08, df = 3 (P = 0.99); I ² = 0% 7 Eee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.82] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] 9 Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] 9 9 9 Total events 6 43 43 9 9 <	l est for overall effect. 2	2 = 0.26 (P = l	1.79)				
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	6.1.4 Pseudomeningo	cele					
Munshi 2010 0 11 2 23 3.5% 0.37 [0.02, 8.46] Mutchnlck 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% Cl) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08, df = 3 (P = 0.99); I ² = 0% Test for overall effect: $Z = 1.72$ (P = 0.09) 6.1.5 Aseptic meningitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.27] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] 17 Total events 0 8 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); I ² = 0% 10 100 Total events 6 43 10 100 10 100 10 10	Gurbuz 2015	0 1	81	12	3.8%	0.21 [0.01, 5.53]	· · · · · ·
Mutchnick 2010 0 56 2 64 5.1% 0.22 [0.01, 4.71] Subtotal (95% Cl) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08, df = 3 (P = 0.99); I ² = 0% 7 Test for overall effect: $Z = 1.72$ (P = 0.09) 6.1.5 Aseptic meningitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.82] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] 10 Total events 0 8 8 8 195% Cl) 566 747 100.0% 0.34 [0.19, 0.60] 10 Total events 6 43 43 40.19, 0.60] 10 10 100 100 Test for overall effect: Z = 3.66 (P = 0.0003) FED PED <t< td=""><td>McGirt 2008</td><td>0 11</td><td>62</td><td>140</td><td>5.0%</td><td>0.24 [0.01, 5.00]</td><td></td></t<>	McGirt 2008	0 11	62	140	5.0%	0.24 [0.01, 5.00]	
Subtotal (95% CI) 201 239 17.5% 0.25 [0.05, 1.21] Total events 0 7 Heterogeneity: Chi ² = 0.08, df = 3 (P = 0.99); I ² = 0% Test for overall effect: $Z = 1.72$ (P = 0.09) 6.1.5 Aseptic meningitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.82] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% CI) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); I ² = 0% Test for overall effect: $Z = 1.71$ (P = 0.09) Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); I ² = 0% Test for overall effect: $Z = 3.66$ (P = 0.0003) PED PEDD	Munshi 2010	0 1	1 2	23	3.5%	0.37 [0.02, 8.46]	
Total events 0 7 Heterogeneity: $Chi^2 = 0.08$, $df = 3$ (P = 0.99); $l^2 = 0\%$ Test for overall effect: $Z = 1.72$ (P = 0.09) 6.1.5 Aseptic meningitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.82] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); l ² = 0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); l ² = 0% 0.01 0.1 10 100 Test for overall effect: Z = 3.66 (P = 0.0003) PED PED PED PED PED	Mutchnick 2010	05	62	64	5.1%	0.22 [0.01, 4.71]	
Heterogeneity: $Chi^2 = 0.08$, $df = 3$ (P = 0.99); $l^2 = 0\%$ Test for overall effect: $Z = 1.72$ (P = 0.09) 6.1.5 Aseptic meningitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.82] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: $Chi^2 = 0.63$, $df = 3$ (P = 0.89); $l^2 = 0\%$ Test for overall effect: $Z = 1.71$ (P = 0.09) Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: $Chi^2 = 10.77$, $df = 22$ (P = 0.98); $l^2 = 0\%$ Test for overall effect: $Z = 3.66$ (P = 0.0003)	Subtotal (95% CI)	20	1	239	17.5%	0.25 [0.05, 1.21]	
Test for overall effect: $Z = 1.72$ (P = 0.09) 6.1.5 Aseptic meningitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.82] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% CI) 71 116 17.5% 0.26 [0.05, 1.22] Image: the temperature of the temperature of temperatur	Total events	0	7				
6.1.5 Aseptic meningitis Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.82] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% CI) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); l ² = 0% Test for overall effect: Z = 1.71 (P = 0.09) Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); l ² = 0% Test for overall effect: Z = 3.66 (P = 0.0003) 0.01 0.1	Heterogeneity: Chi ² = 0).08, df = 3 (P	= 0.99); l ² =	0%			
Lee 2014 0 29 3 36 6.8% 0.16 [0.01, 3.27] Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.82] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); $I^2 = 0\%$ Test for overall effect: Z = 1.71 (P = 0.09) Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); $I^2 = 0\%$ Test for overall effect: Z = 3.66 (P = 0.0003) PED PEDD	Test for overall effect: 2	Z = 1.72 (P = 0).09)				
Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.82] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); l ² = 0% Test for overall effect: $Z = 1.71$ (P = 0.09) Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); l ² = 0% Test for overall effect: $Z = 3.66$ (P = 0.0003) PED PEDD	6.1.5 Aseptic meningi	tis					
Limonadi 2004 0 12 1 12 3.2% 0.31 [0.01, 8.31] Romero 2010 0 6 3 10 5.6% 0.16 [0.01, 3.82] Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); l ² = 0% Test for overall effect: $Z = 1.71$ (P = 0.09) Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); l ² = 0% Test for overall effect: $Z = 3.66$ (P = 0.0003) PED PEDD	Lee 2014	0 2	93	36	6.8%	0.16 [0.01, 3.27]	· · · · · · · · · · · · · · · · · · ·
Yilmaz 2011 0 24 1 58 1.9% 0.78 [0.03, 19.88] Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); l ² = 0% 747 100.0% 0.34 [0.19, 0.60] Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); l ² = 0% 0.01 0.1 10 100 Test for overall effect: Z = 3.66 (P = 0.0003) PED PED PED PED	Limonadi 2004	0 1	21	12	3.2%	0.31 [0.01, 8.31]	
Subtotal (95% Cl) 71 116 17.5% 0.26 [0.05, 1.22] Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); l ² = 0% Test for overall effect: $Z = 1.71$ (P = 0.09) Total events 6 10 100.0% Test for overall effect: $Z = 1.77$, df = 22 (P = 0.98); l ² = 0% Test for overall effect: $Z = 3.66$ (P = 0.0003)	Romero 2010	0	63	10	5.6%	0.16 [0.01, 3.82]	· · · · · ·
Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); I ² = 0% 7 Test for overall effect: Z = 1.71 (P = 0.09) 0.34 [0.19, 0.60] Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); I ² = 0% 0.01 0.1 1 10 100 Test for overall effect: Z = 3.66 (P = 0.0003) PED PED PED PED	Yilmaz 2011	0 2	4 1	58	1.9%	0.78 [0.03, 19.88]	
Total events 0 8 Heterogeneity: Chi ² = 0.63, df = 3 (P = 0.89); l ² = 0% 7 Test for overall effect: Z = 1.71 (P = 0.09) 6 747 100.0% 0.34 [0.19, 0.60] Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); l ² = 0% 0.01 0.1 10 100 Test for overall effect: Z = 3.66 (P = 0.0003) PED PED PED PED	Subtotal (95% CI)	7	1	116	17.5%		
Heterogeneity: $Chi^2 = 0.63$, $df = 3$ (P = 0.89); $l^2 = 0\%$ Test for overall effect: Z = 1.71 (P = 0.09) Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: $Chi^2 = 10.77$, $df = 22$ (P = 0.98); $l^2 = 0\%$ Test for overall effect: Z = 3.66 (P = 0.0003) PED PEDD	Total events	0	8			-	
Total (95% Cl) 566 747 100.0% 0.34 [0.19, 0.60] Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); l ² = 0% 0.01 0.1 1 10 100 Test for overall effect: Z = 3.66 (P = 0.0003) PED PED PED PED	Heterogeneity: Chi ² = 0).63, df = 3 (P	= 0.89); I ^z =	0%			
Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); l ² = 0% 0.01 0.1 1 10 100 Test for overall effect: Z = 3.66 (P = 0.0003) PED_PEDD PED_PEDD PED_PEDD							
Total events 6 43 Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); l ² = 0% 0.01 0.1 1 10 100 Test for overall effect: Z = 3.66 (P = 0.0003) PED_PEDD PED_PEDD PED_PEDD	Total (95% CI)	56	6	747	100.0%	0.34 [0.19, 0.60]	•
Heterogeneity: Chi ² = 10.77, df = 22 (P = 0.98); l ² = 0% 0.01 1 10 100 Test for overall effect: Z = 3.66 (P = 0.0003) PED_PEDD PED_PEDD PED_PEDD	Total events	6	43				
Test for overall effect: Z = 3.66 (P = 0.0003)		0.77, df = 22		l² = 0%			
Test for subaroup differences: Chi² = 3.31. df = 4 (P = 0.51). I² = 0%							
	Test for subaroup diffe	rences: Chi²	= 3.31. df =	4 (P =	0.51). I² =	0%	

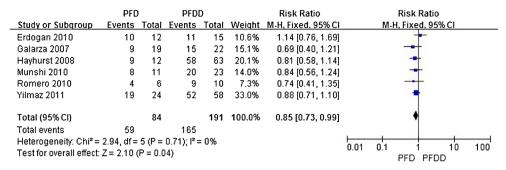


Fig. 4 There is no difference in the clinical improvement rate between the two groups [mean difference = 0.55, 95 % CI (0.27, 1.10), p > 0.05]. Subgroup analysis shows that improvement rate is not significant both in

children [mean difference = 0.49, 95 % CI (0.18, 1.35), p > 0.05] and adults [mean difference = 0.55, 95 % CI (0.23, 1.60), p > 0.05]

Clinical improvement

Six studies [9, 10, 13, 16, 21, 31] recorded the clinical improvement rate. There is significant difference in the clinical improvement rate between the two groups in favor of the PFDD group [mean difference=0.85, 95 % CI (0.73, 0.99), p < 0.05].

Critical appraisal

The population and study eligibility criteria are accurately defined, insuring comparable parameters are balanced and efficient in the study groups. Related research questions can be clearly addressed by appropriate selection and definition of the outcome measures. However, methodological limitations still exist in the literature (Table 2). Several factors may bias the findings of the current study. First, bias can be introduced in a retrospective review that does not have randomized, prospectively matched groups. Second, because both the practitioners and evaluators are surgeons, the design of the project

cannot be absolutely blinded to which surgery was operated and clinical improvements such as numbness and tingling are hardly objective. Third, Some studies may reserve bony decompressions for mild cases or patients without syringomyelia and PFDD for the more severe cases which could incur bias. In both PFD and PFDD groups, the bony decompression range may also influence our results. Other confounding factors could be the operative decisions and techniques of the different surgeons. Some studies' follow-up periods are quite short, and it may also affect the results. Multiple alternative factors, such as the implementation of tonsillar resection, the adoption of intraoperative ultrasound, and the different material used for duraplasty, could affect the outcome. This, therefore, permitted bias.

Discussion

The CM-I constitutes a group of congenital or acquired etiology that has descent of the cerebellar tonsils into the cervical

 Table 2
 Risk of bias assessment of included studies

Paper	Adequate sequence generation?	Allocation concealment used	Blinding	Interventions clearly defined	Outcome measures clearly defined	Outcome measures appropriate	Appropriate follow-up duration
Chotai 2014	Yes	No	No	Yes	Yes	Yes	Yes
Erdogan 2010	Yes	No	No	Yes	Yes	Yes	Unclear
Galarza 2007	Yes	No	No	Yes	Yes	Yes	Yes
Gurbuz 2014	Yes	No	No	Yes	Yes	Yes	Yes
Lee 2014	Yes	No	No	Yes	Yes	Yes	Yes
Limonadi 2004	Yes	No	No	Yes	Yes	Yes	Yes
MutchnIck 2010	Yes	No	No	Yes	Yes	Yes	Yes
Yilmaz 2010	Yes	No	No	Yes	Yes	Yes	Yes
Romero2010	Yes	No	No	Yes	Yes	Yes	Yes
Munchi 2000	Yes	No	No	Yes	Yes	Yes	Yes
Hayhurst 2008	Yes	No	No	Yes	Yes	Yes	Yes
McGrit 2007	Yes	No	No	Yes	Yes	Yes	Yes

spinal canal. The surgical indications of CM-I were usually headache (or tussive headache); neck, arm, or back pain; swallowing difficulties; drop attacks; or upper extremity numbness or tingling. The presence of a syrinx was also an indication for surgery when it occurred in the presence of the above symptoms [4, 5, 11, 20].

For these patients and neurosurgeons, the clinical improvement is the most priority for the surgical decision making. Generally, the postoperation symptomatic improvement has been reported in the range of 61.5–93 % from different studies [5, 6, 8, 16, 17]. Some studies indicated that PFDD is better at least for patients with syringomyelia and some report clinical results as comparable [21, 30]. According to our results, PFDD can achieve more satisfactory outcomes than PDF can in the clinical improvement between the two groups.

Some studies also reported the imaging improvement which is not as good as the clinical improvement [10, 12, 15, 31]. Though the compression has been relieved by surgical decompression, arachnoid scarring prevents the nervous structures to regain its normal position [10, 24]. However, the minimal enlargement of the subarachnoid spaces at the craniocervical junction resulting from bone decompression was sufficient to relieve the impact on the nervous structures and to improve CSF circulation. There is also no significant correlation between the reduction in syrinx size on MRI and the degree of clinical improvement [8, 10, 16, 29, 30]. Although clinical symptoms do not correlate to the presence or size of preoperative syringomyelia, there can be no doubt that a permanent postoperative reduction of syrinx size is an indicator of a sufficient decompression. On the contrary, the lower numbers for postoperative syrinx reductions in the bony decompression group must be seen as a prognostic indicator for worse long-term results. It implies that neurosurgeons should focus on both clinical outcome and radiological findings.

To better evaluate the effectiveness of PFD and PFDD in the management of CM-I, many researchers reported the re-operation rates [7, 9, 10, 15, 21, 22]. Once it occurs, the patients will suffer from tremendous pain and heavy economic burden. We hold the opinion that the re-operation may be caused by two main reasons: the persistence symptoms or the severe complications. Due to insufficient data, the different reasons of re-operation cannot be meta-analyzed in this paper. However, according to some research and our experience, more second surgeries had been done because of the recurrent syndromes such as nausea and vomiting rather than severe complications. Many studies observed a trend for lower recurrence rates in the PFDD group; whether this trend reaches the level of significance remains to be tested. For the patients who have recurrent clinical symptoms after PFD, a second PFDD can achieve better effect [1, 8, 15, 21, 26, 27].

For the other important aspect, PFD is associated with lesser rate of overall complications compared with PFDD especially in the CSF leak complication according to our results which reduces the re-operation to a great degree. The CSF-related complications include postoperative CSF leak, pseudomeningocele formation, meningitis, and scarring of the arachnoid leading to obstruction of CSF dynamics and foreign-body reaction [1, 3]. Most complications are related to CSF exposure to blood and muscle cellular debris as well as the use of dural graft. Thus, extradural decompression without duraplasty will be associated with lesser complication rates. Like previous studies [16, 23], we also found that the PFD group had shorter operative time than did the PFDD group. Besides, many researches have reported that PFD leads to shorter hospital stay lengths and less hospitalization costs [8, 17, 27].

CM-I is often associated with other medical conditions such as syringomyelia. Recent studies have reported an incidence rate as high as 70–80 % for syringomyelia [10, 28–30]. The range of the decrease rate of syringomyelia is wide (55–100 %) according to previous reports [8–10, 12, 16, 20, 26, 30]. Though not statistically significant, some findings also show higher rates of syrinx improvement in patients undergoing PFDD [23, 28–30]. Despite these findings, recently, a large sample study by Shweikeh [27] shows that CM-I patients with syringomyelia or hydromyelia were more often treated with PFD rather than PFDD. It is possible that the presence of syringomyelia does not currently influence treatment decisions.

Above all, for the criteria of the surgical decision making, we believe that for those with rapidly progressive symptoms or severe neurological deficits, previous research advises PFDD as the first option. While for patients with mild symptoms and no syringomyelia, PFD could be the first choice. If symptoms fail to improve, PFDD should be considered. According to our results, PFDD is better with improving rates but with more surgical trauma and higher rate of CSF leak. So, which is the preferable choice for those patients? As for the decompression surgery, our aim is to restore normal CSF dynamics at the level of the craniocervical junction. Thus, intraoperative ultrasonography may be a useful tool to aid the surgeon in deciding whether to adopt PFD or PFDD and even tonsillar shrinkage. Recently, more and more studies demonstrate that intraoperative ultrasonography can effectively guide the surgical decision making [14, 19, 32].

Conclusion

Although PFDD is related with longer operation time and higher CSF leak rate, it can still be considered as a preferable treatment option for most CM-I patients for its higher improvement rate. And PFDD tends to be worthy of consideration under the circumstance of failed PFD. More evidence from advanced multi-center studies are needed to provide illumination for the surgical decision making of CM-I.

Acknowledgements This work has no founding source.

Compliance with ethical standards

Competing interests The authors declare that they have no competing interests.

References

- Abla AA, Link T, Fusco D, Wilson DA, Sonntag VK (2010) Comparison of dural grafts in Chiari decompression surgery: review of the literature. J Craniovertebr Junction Spine 1:29–37
- Aboulezz AO, Sartor K, Geyer CA, Gado MH (1985) Position of cerebellar tonsils in the normal population and in patients with Chiari malformation: a quantitative approach with MR imaging. J Comput Assist Tomogr 9:1033–1036
- Benglis D Jr, Covington D, Bhatia R, Bhatia S, Elhammady MS, Ragheb J, Sandberg DI (2011) Outcomes in pediatric patients with Chiari malformation type I followed up without surgery: clinical article. J Neurosurg Pediatr 7:375–379
- Cahan LD, Bentson JR (1982) Considerations in the diagnosis and treatment of syringomyelia and the Chiari malformation. J Neurosurg 57:24–31
- Caldarelli M, Novegno F, Vassimi L, Romani R, Tamburrini G, Di Rocco C (2007) The role of limited posterior fossa craniectomy in the surgical treatment of Chiari malformation type I: experience with a pediatric series. J Neurosurg 106:187–195
- Chauvet D, Carpentier A, George B (2009) Dura splitting decompression in Chiari type 1 malformation: clinical experience and radiological findings. Neurosurg Rev 32:465–470
- Chotai S, Medhkour A (2014) Surgical outcomes after posterior fossa decompression with and without duraplasty in Chiari malformation-I. Clin Neurol Neurosurg 125:182–188
- Durham SR, Fjeld-Olenec K (2008) Comparison of posterior fossa decompression with and without duraplasty for the surgical treatment of Chiari malformation type I in pediatric patients: a metaanalysis. J Neurosurg Pediatr 2:42–49
- Erdogan E, Cansever T, Secer HI, Temiz C, Sirin S, Kabatas S (2010) The evaluation of surgical treatment options in the Chiari malformation type I. Turk Neurosurg 20:303–313
- Galarza M, Sood S, Ham S (2007) Relevance of surgical strategies for the management of pediatric Chiari type I malformation. Childs Nerv Syst 23:691–696
- Genitori L, Peretta P, Nurisso C, Macinante L, Mussa F (2000) Chiari type I anomalies in children and adolescents: minimally invasive management in a series of 53 cases. Childs Nerv Syst 16: 707–718
- Gurbuz MS, Karaaslan N, Caliskan T, Unal E, Berkman MZ (2015) Comparison of the surgical results for foramen magnum

decompression with and without duraplasty in Chiari malformation type 1. Turk Neurosurg 25:419–424

- Hayhurst C, Richards O, Zaki H, Findlay G, Pigott TJ (2008) Hindbrain decompression for Chiari - syringomyelia complex: an outcome analysis comparing surgical techniques. Br J Neurosurg 22(1):86–91
- Klekamp J (2012) Surgical treatment of Chiari I malformation analysis of intraoperative findings, complications, and outcome for 371 foramen magnum decompressions. Neurosurgery 71:365–380
- Lee A, Yarbrough CK, Greenberg JK, Barber J, Limbrick DD, Smyth MD (2015) Comparison of posterior fossa decompression with or without duraplasty in children with type I Chiari malformation. Childs Nerv Syst 30:1419–1424
- Limonadi FM, Selden NR (2004) Dura-splitting decompression of the craniocervical junction: reduced operative time, hospital stay, and cost with equivalent early outcome. J Neurosurg 101:184–188
- Litvack ZN, Lindsay RA, Selden NR (2013) Dura splitting decompression for Chiari I malformation in pediatric patients: clinical outcomes, healthcare costs and resource utilization. Neurosurgery 72:922–929
- Massimi L, Novegno F, di Rocco C (2011) Chiari type I malformation in children. Adv Tech Stand Neurosurg 37:143–211
- McGirt MJ, Attenello FJ, Datoo G, Gathinji M, Atiba A, Weingart JD, Carson B, Jallo GI (2008) Intraoperative ultrasonography as a guide to patient selection for duraplasty after suboccipital decompression in children with Chiari malformation Type I. J Neurosurg Pediatr 2:52–57
- Munshi I, Frim D, Stine-Reyes R, Weir BK, Hekmatpanah J, Brown F (2000) Effects of posterior fossa decompression with and without duraplasty on Chiari malformation-associated hydromyelia. Neurosurgery 46:1384–1389
- Mutchnick IS, Janjua RM, Moeller K, Moriarty TM (2010) Decompression of Chiari malformation with and without duraplasty: morbidity versus recurrence. J Neurosurg Pediatr 5: 474–478
- Navarro R, Olavarria G, Seshadri R, Gonzales-Portillo G, McLone DG, Tomita T (2004) Surgical results of posterior fossa decompression for patients with Chiari I malformation. Childs Nerv Syst 20: 349–356
- Park JK, Gleason PL, Madsen JR, Goumnerova LC, Scott RM (1997) Presentation and management of Chiari I malformation in children. Pediatr Neurosurg 26:190–196
- Ramirez LF, Thisted R (1989) Using a national health care data base to determine surgical complications in community hospitals: lumbar discectomy as an example. Neurosurgery 25:218–225
- Romero FR, Pereira CA (2010) Suboccipital craniectomy with or without duraplasty: what is the best choice in patients with Chiari type 1 malformation? Arq Neuropsiquiatr 68:623–626
- Sakamoto H, Nishikawa M, Hakuba A, Yasui T, Kitano S, Nakanishi N, Inoue Y (1999) Expansive suboccipital cranioplasty for the treatment of syringomyelia associated with Chiari malformation. Acta Neurochir 141:949–961
- Shweikeh F, Sunjaya D, Nuno M, Drazin D, Adamo MA (2015) National trends, complications, and hospital charges in pediatric patients with Chiari malformation type I treated with posterior fossa decompression with and without duraplasty. Pediatr Neurosurg 50: 31–37
- Tubbs RS, McGirt MJ, Oakes WJ (2003) Surgical experience in 130 pediatric patients with Chiari I malformations. J Neurosurg 99: 291–296
- Ventureyra ECG, Aziz HA, Vassilyadi M (2003) The role of cine flow MRI in children with Chiari I malformation. Childs Nerv Syst 19:109–113
- Yeh DD, Koch B, Crone KR (2006) Intraoperative ultrasonography used to determine the extent of surgery necessary during posterior

fossa decompression in children with Chiari malformation type I. J Neurosurg 105:26–32

- Yilmaz A, Kanat A, Musluman AM, Çolak I, Terzi Y, Kayacı S, Aydin Y (2011) When is duraplasty required in the surgical treatment of Chiari malformation type I based on tonsillar descending grading scale? World Neurosurg 75:307–313
- (2014) The case for duraplasty in adults undergoing posterior fossa decompression for Chiari I malformation: a systematic review and meta-analysis of observational studies. Clin Neurol Neurosurg 125: 58–64

Comments

Luca Massimi, Rome, Italy

The treatment of Chiari type I malformation continues to raise interest and debate. A well-known issue concerns the management of asymptomatic/poorly symptomatic subjects. A further and still disputed one concerns the best surgical operation. Actually, many kind of surgical treatments are adopted in different centers, ranging from the bony decompression of the posterior cranial fossa alone (craniectomy with or without C1 laminectomy) to the coagulation of tonsils passing through the expanding decompressive craniotomy, the dural delamination, and the duraplasty. All these surgical approaches seem to ensure good clinical results with some differences as far as the radiological outcome and the complications are concerned. On these grounds, an updated systematic review and meta-analysis of the literature was needed.

The review proposed by Xu and coworkers is focused on the "dilemma" between posterior fossa decompression alone (PFD) or with duraplasty (PFDD). As expected, PFD showed lower operating times and lower rates of complications compared with PFDD. However, PFDD showed better clinical outcome and lower risk of recurrence. Similar results were collected by Durham and Fjeld-Olenec in a previous meta-analysis on pediatric patients [8]. The confirmation provided by Xu et al. in a larger and mixed population (children and adults), therefore, would allow the neurosurgeons to definitely identify the PFDD as more effective than PFD, though more risky. Nevertheless, as stressed by the authors, several biases burden the study, as the different criteria for indication and evaluation of the results adopted by the authors of the analyzed papers, the use of retrospective series, the extent of bone decompression, the length of follow-up, or the materials used for the duraplasty. In addition, the inability to achieve a systematic correlation between clinical and radiological findings deprives this meta-analysis of information on the trend of the CSF dynamics in the posterior fossa (cisterna magna reexpansion) and the spinal cord (decrease of syringomyelia). This reinforces the need for multicenter randomized trials.

The goal of the surgical treatment of Chiari type I is to restore the CSF spaces at the craniocervical junction. In spite of the obtained results, the authors do not solve the dilemma about the best solution between PFD and PFDD. They propose intraoperative ultrasounds as the method to evaluate the restoration of the cisterna magna and, consequently, the need for a duraplasty. Such a strategy is already used by many authors (including the author of the present comment) and gives reasons of some results found in the literature and some possible biases. Indeed, intraoperative MRI, utilized for the same purpose in a recent prospective series, demonstrated an improvement of the CSF flow with the prone position alone so good that it was not significantly enhanced after PFD (Bond AE et al., J Neurosurg 122: 1068-1075, 2015). This observation, unfortunately, offers a further intraoperative bias. For these reasons, the surgical management of Chiari I should continue to be tailored on the single patient based on preoperative clinical and radiological criteria (PFD for poorly symptomatic patients without syringomyelia, PFDD for clearly symptomatic ones with syringomyelia) other than on intraoperative radiological criteria. Similarly, children should be differentiated from adults.

Actually, pediatric patients do not infrequently show a moderate tonsillar herniation that is hard to be correlated with the clinical picture and that is not associated with syringomyelia (or is associated with thin hydromyelia). In these instances, also due to the residual potential of growth of the posterior fossa and the increased risk of CSF leakage in children, PFD alone should be considered.

Jörg Klekamp, Quakenbrück, Germany

The authors of this paper propose to leave the dura open after decompression of the foramen magnum for patients with Chiari I malformation in order to avoid problems with dura grafts and formation of arachnoid adhesions between dura or duragraft and underlying cerebellar and spinal cord tissue. This is a concept originally used by Gardner in his paper from 1965. Bernard Williams adopted this strategy fearing reobstruction of CSF pathways by arachnoiditis when dura grafts are used. He was convinced that duraplasties should be avoided whenever creating a sustained CSF passage was part of the surgical strategy. I had many personal discussions with him on this subject without ever agreeing on this issue. While working in Hannover, a number of patients were actually operated leaving the dura open. Their results, however, were considerably worse compared to patients operated with duraplasties, so this technique was quickly abandoned:

1. Leaving the dura open allows breakdown products of blood or muscle proteins to contaminate the subarachnoid space. This causes a severe arachnoiditis. If such areas are reopened surgically a few months or years later, the entire area usually appears covered by a thick, whitish membrane. It is no longer possible to identify any blood vessels on the cord surface or caudal cranial nerves lateral of the cervical cord and medulla oblongata. If the foramen of Magendie is closed by this membrane, any attempt of opening it is extremely dangerous for lack of any anatomical landmarks. When this technique had been used in the spinal canal, the CSF passage was regularly found to be obstructed due to this arachnoiditis upon reopening.

2. Leaving the dura open puts patients at risk to develop superficial siderosis, which is a potentially life-threatening complication related to repeated contaminations of CSF with blood. Bernard Williams operated on a woman with Chiari I malformation in Hannover during an instructional course in 1990 leaving the dura open. The patient did well postoperatively for about 1 year when she started to demonstrate signs of this disease causing severe gait and hearing problems.

3. With time, bulging of neck muscles may lead to a progressive decrease of the subarachnoid space at the foramen magnum even to the point of complete obstruction of CSF flow. Although I have seen such cases presented in scientific meetings by British neurosurgeons, who widely adopted Williams' technique in the 1980s and 1990s, this late complication has not been published to my knowledge.

Therefore, I cannot agree with the authors of this paper and strongly advise against the technique of leaving the dura open for patients with Chiari decompressions or other pathologies.

Giannantonio Spena, Brescia, Italy

In this interesting paper from Xu et al., the authors perform a metaanalyis of the last two decades literature in order to clarify if posterior fossa decompression with (PFDD) and without (PFD) duroplasty shows differences in terms of outcomes.

The quest for the perfect intervention on Chiari I malformation (CMI) has led many authors to try many different approaches. By looking at the last decades, surgery for CMI has become more minimally invasive with the aim to reducing complications. In fact, intraarachnoid manipulation, although performed with success by several authors, intrinsically exposes the patient to risks. Moreover, adding tonsillar and arachnoid manipulation does not seem to bring further improvement to outcomes. Proposing an osseous decompression without duroplasty has become the natural consequence of chasing the most atraumatic surgery. Unfortunately, as pointed out in this meta-analysis, leaving the dura mater intact can potentially augment the number of redo surgery due to an insufficient

reducing operative times.

the CSF dynamics follows completely different rules in young patients leading to higher numbers of external fistulas. In our opinion, this strategy

is also preferable in those rare elderly patients where the aim is to guar-

antee relief of symptoms while avoiding any possible complications and

221

One aspect that should be regarded with interest is that, despite different technical nuances, recent literature demonstrates that a certain percentage of patients does not benefit from decompression. It is difficult sometimes to predict clinical result, but today, it is clear that one of the first causes of unsatisfying results is an incomplete diagnosis. This implies not only to mistake a cerebellar tonsils' ecotopia with CMI but also to neglect many other structural alterations (craniocervical-associated malformations, instability, cerebrospinal fluid's dynamic alterations) which require sometimes different or multiple treatments.