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Review Article

Prevalence of hematoma after anterior cervical spine surgery: a meta-analysis

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Abstract: Background: Hematoma is a well-known complication following anterior cervical spine surgery. A lot of literatures have reported the incidence of hematoma but no meta-analysis of the epidemiological data on hematoma has been published. Objective: The purpose of this review is to investigate the prevalence of hematoma following anterior cervical spine surgery by meta-analysis. Methods: PUBMED, CNKI and WANFANG database were searched for articles reported the incidence of hematoma following anterior cervical spine surgery. Sample size and number of hematoma were extracted. Incidence rate with 95% confidence intervals (CI) were calculated for each articles. Then we pooled the data to derive a pooled incidence rate and 95% CI. Data analysis was conducted with the software STATA 12.0. Results: A total of 95 studies with 34497 patients were included in the final analysis. The pooled analysis showed that the prevalence of total hematoma was 0.8% (95% CI 0.7%-1.0%), that of wound hematoma 1.0% (95% CI 0.7%-1.2%) and epidural hematoma 0.4% (95% CI 0.3%-0.5%). In anterior cervical corpectomy and fusion (ACCF) and anterior cervical decompression and fusion (ACDF) subgroup, the prevalence of hematoma were 0.4% and 1.0% respectively. In cervical spondylotic myelopathy (CSM) and ossification of the posterior longitudinal ligament (OPLL) subgroup, the prevalence of hematoma were 0.3% and 4.2% respectively. In China, America, France, Germany and Norway subgroup, the prevalence of hematoma were0.7%, 1.0%, 0.5%, 1.7% and 1.4% respectively. In Chinese and English subgroup, the prevalence of hematoma were 0.7% and 1.1% respectively. In retrospective, prospective and randomized controlled trial (RCT) subgroup, the prevalence of hematoma were 0.8%, 1.4% and 1.0% respectively. Conclusions: Anterior cervical spine surgery is associated with higher risk of hematoma particularly in wound hematoma, OPLL patients, ACDF surgery and Germany subgroup. These figures may be useful in the estimation of the probability of hematoma following anterior cervical spine surgery. Considering the statistical heterogeneity and publication bias, this conclusion should be interpreted cautiously.

Keywords: Prevalence, hematoma, anterior, cervical spine, meta-analysis

Introduction

Anterior cervical spine surgery is commonly performed for treatment of cervical spine pathologies including trauma and degenerative spinal diseases [1-5]. The anterior approach is safe, effective, and associated with low rates of morbidity and mortality [6]. However, a number of complications associated with the anterior approach have been described [7]. Postoperative hematoma is reported as a rare but fatal early complication after anterior cervical spine surgery [8-12].

Postoperative hematoma includes wound hematoma and epidural hematoma [13]. Wound hematoma refers to the accumulation of blood in the retropharyngeal space or subcutaneous tissue which can quickly result in airway compromise [14, 15]. Epidural hematoma refers to the accumulation of blood in the epidural space which may cause severe cord compression and tetraplegia [16-18]. Both of the two types of hematoma require fast recognition and action to prevent catastrophic patient morbidity or death [19-25].

However, there is lack of recognized understanding about the etiology, pathomechanism, prevention, and even epidemiological assessment of hematoma after anterior cervical spine surgery [26]. To our knowledge, no meta-analysis of the epidemiological data on hematoma has been published. The purpose of this review is to investigate the prevalence of hematoma following anterior cervical spine surgery by meta-analysis and to provide available and detailed epidemiological data for pre-operative estimation and provide informed consent.

Materials and methods

Search methods and selection of studies

An extensive search of literatures was performed on PUBMED, CNKI (Chinese database) and WANFANG (Chinese database) up to August 2016. The languages were restricted to Chinese or English. The following key words were used for search: "hematoma", "anterior", "cervical spine", "surgery", and "operation". The reference lists of included studies were also handsearched for additional qualified studies.

Inclusion criteria

Eligible studies were selected according to the following criteria: (1) mentioned the incidence of hematoma following anterior cervical spine surgery; (2) sufficient reported data for extraction and calculation of an incidence rate with 95% CI; (3) a prospective study, retrospective study or RCT; (4) in the case of duplicate publication, the largest or most recent study was selected; (5) publications were excluded if they were case reports, review articles, letters, editorials, animal trials, or cadaver studies. Two reviewers independently reviewed all subjects, abstracts, and the full text of articles. Then the eligible trials were selected according to the inclusion criteria. When consensus could not be reached, a third reviewer was consulted to resolve the disagreement.

Data extraction

For each included study, the following information was extracted independently by two reviewers on a standard data extraction form: the first author's name, publication year, country, study design, sample size, number of hematoma, hematoma type, disease pattern and surgical type. When consensus could not be reached, a third reviewer was consulted to resolve the disagreement.

Quality rating

The included studies were evaluated independently by two reviewers using a published quality rating system designed especially for studies reporting on prevalence [27]. The 5 points scale system included: (1) the study design was appropriate for obtaining prevalence estimates; (2) the sample was representative of the general population of patients after anterior cervical spine surgery; (3) the hematoma diagnostic criteria was acceptable (Wound hematoma refers to the accumulation of blood in the retropharyngeal or subcutaneous tissue which can quickly result in airway compromise. Epidural hematoma refers to the accumulation of blood in the epidural space which may cause severe cord compression and tetraplegia. All the hematoma cases were diagnosed by symptom, MRI scan or reoperation); (4) clinical diagnosis were performed on a consecutive or random sample of subjects; (5) the final diagnosis was known for 80% of eligible subjects [30].

Statistical analysis

We conducted a meta-analysis using STATA 12.0 (Stata Corporation, College Station, TX, USA) for all extracted data [28]. Heterogeneity across studies was estimated by using Cochran's Chi square-based Q statistic and I^2 test (I^2 = 0-25% represents no heterogeneity, I^2 = 25-50% represents moderate heterogeneity, I^2 = 50-75% represents large heterogeneity, I^2 = 75-100% represents extreme heterogeneity) [29]. When a significant Q test ($P < 0.10$) or $I^2 >$ 50% indicated heterogeneity across studies, the random effects model was used for meta-analysis, otherwise the fixed effects model was used [30]. We calculated the point prevalence of hematoma with its 95% CI for each individual study, and then a pooled prevalence estimate and 95% CI were generated [31]. Subgroup analysis was performed based on hematoma type, country, disease pattern, language, study design and surgical type. $P < 0.05$ was used as the level of statistical significance. Sensitivity analysis was conducted to examine the influence of excluding each study [32]. Potential publication bias was assessed by the Begg funnel plots and the Egger test.

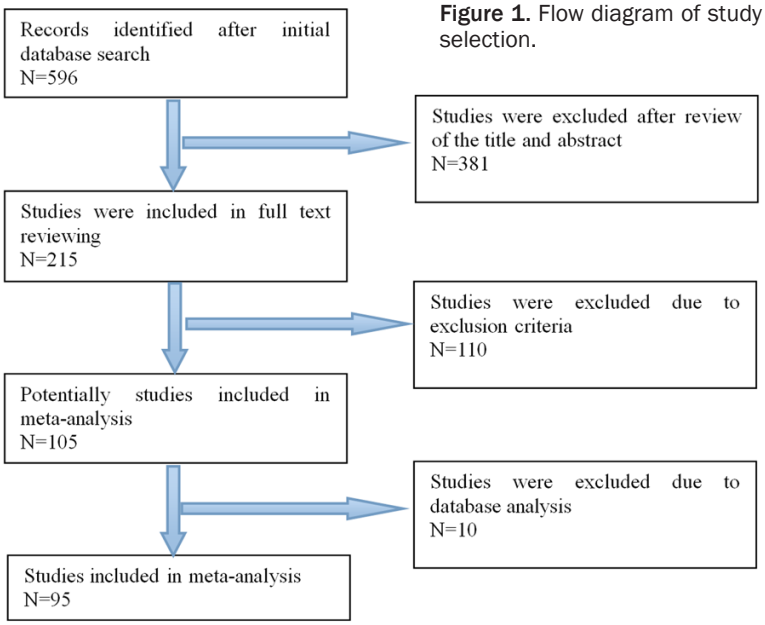

Figure 1. Flow diagram of study selection.

Results

Search results

A total of 596 records were identified by the initial database search. Three hundred and eighty-one records were excluded after reviewing the titles and abstracts. A full text review was accessed in the retaining 215 studies and 110 of them were excluded according to the inclusion criteria. Another ten articles were excluded because all data of the ten articles were from the American Nationwide In patient Sample database and they might be repeated with other studies. Finally, 95 articles that met our inclusion criteria were included in the present meta-analysis [1-26, 33-101]. The selection process was shown in **Figure 1**.

Baseline characteristics and quality assessment

Finally, a total of 95 studies with 34,497 patients met our inclusion criteria were included in the final analysis. Among them, 61 articles were published in Chinese and 34 articles in English. The sample sizes of the included studies ranged from 22 to 3163. The main characteristics of the included studies were listed in **Table 1**.

Table 1 showed that the quality score of the included 95 studies was 3 to 5 points. The main reasons for not reaching the required 5 points were the study design which was not appropriate for obtaining prevalence estimates or the sample which was not representative of the general population of patients after anterior cervical spine surgery.

Overall prevalence of hematoma

A total of 95 studies reported prevalence of hematoma after anterior cervical spine surgery. The occurrence of hematoma ranged from 0.1% to 9.9%, and the pooled prevalence was 0.8% (95% CI 0.7%-1.0%) by the random effects model (**Table 2**). There was large heterogeneity for hematoma (I^2 = 56.2%, chi-squared = 214.55, P < 0. 001).

A total of 63 studies reported prevalence of wound hematoma after anterior cervical spine surgery. The occurrence of wound hematoma ranged from 0.1% to 5.6%, and the pooled prevalence was 1.0% (95% CI 0.7%-1.2%) by the random effects model (**Table 2**). There was large heterogeneity for hematoma (I^2 = 59.8%, chi-squared = 154.09, P < 0. 001).

A total of 30 studies reported prevalence of epidural hematoma after anterior cervical spine surgery. The occurrence of epidural hematoma ranged from 0.1% to 5.2%, and the pooled prevalence was 0.4% (95% CI 0.3%-0.5%) by the fixed effects model (**Table 2**). There was no heterogeneity for hematoma (I^2 = 0%, chi-squared = 28.72, P = 0.479).

Subgroup analysis

Disease pattern-related hematoma: As the data for other cervical diseases were few, only OPLL and CSM were included and summarized in **Table 2**. The pooled analysis showed that patients with OPLL had a higher prevalence estimate 4.2% (95% CI 0.6%-7.8%) than those with CSM 0.3%(95% CI 0%-0.5%).

Surgical type-related hematoma: **Table 2** summarized the pooled prevalence estimates based on surgical type. The pooled analysis

Table 1. Characteristic of studies included in this meta-analysis

Author	Year	Country	Language	Study design	Sample size	Hematoma (N)	Hematoma type	Disease pattern	Surgical type	Level of evidence
Lai et al. [1]	2009	China	Chinese	Retrospective	30	1	Epidural	NA	NA	3
Tian et al. [2]	2010	China	Chinese	Retrospective	58	1	Wound	NA	NA	3
Wang et al. [3]	2013	China	Chinese	Retrospective	120	1	Epidural	CSM	NA	4
He et al. [4]	2011	China	Chinese	Retrospective	228	1	Wound	NA	NA	4
Zhang et al. [5]	2011	China	Chinese	Retrospective	59	2	NA	CSM	NA	3
Che et al. [6]	2008	China	Chinese	Retrospective	35	1	Wound	NA	NA	3
Zou et al. [7]	2012	China	Chinese	Retrospective	120	1	Epidural	CSM	NA	4
Liu et al. [8]	2007	China	Chinese	Retrospective	312	1	Wound	CSM	NA	4
Lu et al. [9]	2011	China	Chinese	Retrospective	749	1	Epidural	CSM	NA	4
Shen et al. [10]	2010	China	Chinese	Retrospective	1522	25	Wound	NA	NA	5
Zhao et al. [11]	2008	China	Chinese	Retrospective	282	4	Wound	NA	NA	4
Yang et al. [12]	2014	China	Chinese	Retrospective	184	1	Wound	NA	NA	4
Chen et al. [13]	2003	China	Chinese	Retrospective	86	1	Epidural	NA	NA	3
Li et al. [14]	2010	China	Chinese	Retrospective	65	2	NA	NA	NA	3
Li et al. [15]	2011	China	Chinese	Retrospective	56	2	Epidural	NA	NA	3
Lu et al. [16]	2014	China	Chinese	Retrospective	785	12	Epidural/wound	NA	NA	5
Yin et al. [17]	2013	China	Chinese	Retrospective	213	2	Epidural	NA	NA	3
Yu et al. [18]	2015	China	Chinese	Retrospective	79	1	Wound	NA	NA	3
Aili et al. [19]	2010	China	Chinese	Retrospective	23	1	Epidural	OPLL	NA	3
Yang et al. [20]	2010	China	Chinese	Retrospective	68	1	Wound	CSM	NA	3
Wang et al. [21]	2012	China	Chinese	Retrospective	239	1	Wound	CSM	NA	4
Zhong et al. [22]	2010	China	Chinese	Retrospective	480	16	Wound	NA	NA	5
Liu et al. [23]	2010	China	Chinese	Retrospective	98	2	Wound	NA	NA	3
Yang et al. [24]	2009	China	Chinese	Retrospective	236	2	Wound	NA	NA	4
Bai et al. [25]	2013	China	Chinese	Retrospective	152	4	NA	NA	NA	4
Zhou et al. [26]	2011	China	Chinese	Retrospective	57	1	Wound	NA	NA	3
Li et al. [33]	2007	China	Chinese	Retrospective	228	3	Wound	NA	NA	4
Chen et al. [34]	2011	China	Chinese	Retrospective	172	6	Wound	NA	NA	3
Chen et al. [35]	2003	China	Chinese	Retrospective	3163	16	Wound	NA	NA	5
Fang et al. [36]	2007	China	Chinese	Retrospective	523	3	Wound	NA	NA	4
Yu et al. [37]	2012	China	Chinese	Retrospective	559	4	Wound	NA	NA	4
Wu et al. [38]	2013	China	Chinese	Retrospective	39	2	Wound	NA	NA	3

Tan et al. [39]	2011	China	Chinese	Retrospective	65	3	NA	NA	NA	3
Song et al. [40]	2014	China	Chinese	Retrospective	226	4	Wound	NA	NA	4
Qian et al. [41]	2015	China	Chinese	Retrospective	258	10	Epidural/wound	NA	NA	5
Yuan et al. [42]	2012	China	Chinese	Retrospective	64	2	Wound	NA	NA	3
Zheng et al. [43]	2005	China	Chinese	Retrospective	412	5	Wound	NA	NA	4
Fan et al. [44]	2011	China	Chinese	Retrospective	186	2	Wound	NA	NA	4
Gan et al. [45]	2009	China	Chinese	Retrospective	58	1	Wound	NA	NA	3
Chen et al. [46]	2012	China	Chinese	Retrospective	156	1	Wound	NA	NA	4
Ren et al. [47]	2011	China	Chinese	Retrospective	71	1	Wound	NA	NA	3
Huang et al. [48]	2007	China	Chinese	Retrospective	57	1	Wound	NA	NA	3
Jiang et al. [49]	2014	China	Chinese	Retrospective	253	2	Wound	NA	NA	4
Wang et al. [50]	2005	China	Chinese	Retrospective	256	1	Wound	NA	NA	4
Hu et al. [51]	2010	China	Chinese	Retrospective	200	1	Epidural	NA	NA	4
Lu et al. [52]	2011	China	Chinese	Retrospective	859	4	Epidural	NA	NA	5
Cao et al. [53]	2013	China	Chinese	Retrospective	228	4	Wound	NA	NA	4
Zhang et al. [54]	2009	China	Chinese	Retrospective	1821	10	Epidural	NA	NA	5
Lv et al. [55]	2011	China	Chinese	Retrospective	892	3	Epidural	NA	NA	4
Li et al. [56]	2008	China	Chinese	Retrospective	1752	4	Epidural	NA	NA	5
Zhou et al. [57]	2015	China	Chinese	Retrospective	312	4	Epidural/wound	NA	NA	5
Li et al. [58]	2010	China	Chinese	Retrospective	358	5	Epidural	NA	NA	4
Song et al. [59]	2013	China	Chinese	Retrospective	1452	5	Epidural	NA	NA	5
Liu et al. [60]	2009	China	Chinese	Retrospective	376	1	Epidural	NA	ACCF	4
Chen et al. [61]	2009	China	Chinese	Retrospective	25	1	Epidural	OPLL	ACCF	3
Wang et al. [62]	2008	China	Chinese	Retrospective	26	1	Epidural	OPLL	ACCF	3
Li et al. [63]	2009	China	Chinese	Retrospective	32	1	Wound	CSM	NA	3
Gu et al. [64]	2011	China	Chinese	Retrospective	106	1	Wound	NA	NA	4
Shao et al. [65]	2015	China	Chinese	Retrospective	52	1	Wound	CSM	NA	3
Li et al. [66]	2014	China	Chinese	Retrospective	356	1	NA	NA	NA	4
Xiao et al. [67]	2008	China	Chinese	Retrospective	32	3	NA	CSM	ACCF	3
Marcelo et al. [80]	2009	Brazil	English	Retrospective	48	1	Wound	NA	NA	3
Garringer et al. [93]	2010	America	English	Retrospective	645	2	Epidural	NA	ACDF	5
Kevin et al. [78]	2014	America	English	Retrospective	2375	17	Wound	NA	NA	5
Bertalanffy et al. [99]	1989	Germany	English	Retrospective	450	10	Epidural/wound	NA	NA	5
Volkmar et al. [91]	1998	Germany	English	Retrospective	96	1	Wound	NA	NA	3
Cho et al. [95]	2005	China	English	RCT	100	1	Wound	NA	ACDF	4

Gwynedd et al. [76]	2006	Australia	English	Prospective	74	1	Wound	NA	NA	4
Shields et al. [71]	2006	America	English	Retrospective	151	15	NA	NA	NA	4
Fountas et al. [94]	2007	America	English	Retrospective	1015	57	Wound	NA	ACDF	5
Lied et al. [84]	2008	Norway	English	Prospective	390	5	Wound	NA	ACDF	4
Tumialan et al. [69]	2008	America	English	Retrospective	200	4	Wound	NA	ACDF	4
Pechlivanis et al. [77]	2008	Germany	English	Prospective	90	1	Wound	NA	NA	4
Kasimatis et al. [89]	2008	Greece	English	Retrospective	74	1	Wound	NA	NA	3
Liu et al. [82]	2009	America	English	Retrospective	109	1	Wound	NA	ACDF	4
Lian et al. [86]	2010	China	English	RCT	105	1	Epidural	CSM	NA	4
Sangala et al. [73]	2010	America	English	Retrospective	100	1	Wound	NA	ACDF	4
Gaizka et al. [98]	2010	Spain	English	Retrospective	71	1	Wound	NA	ACCF	3
Liu et al. [90]	2011	China	English	Retrospective	39	1	Wound	NA	ACDF	3
Guo et al. [92]	2010	China	English	Retrospective	53	1	Epidural	NA	NA	3
Marotta et al. [81]	2011	Italy	English	Retrospective	167	1	Wound	NA	ACDF	4
Lin et al. [83]	2011	China	English	Retrospective	120	3	Epidural	CSM	ACCF	4
Sun et al. [75]	2012	China	English	Retrospective	23	1	Epidural	OPLL	NA	3
Lied et al. [85]	2012	Norway	English	Prospective	96	2	Wound	NA	ACDF	4
Fahed et al. [68]	2012	France	English	Retrospective	26	1	Epidural	CSM	ACCF	3
Carreon et al. [96]	2013	America	English	Retrospective	353	2	Wound	NA	ACDF	4
Tuure et al. [74]	2012	Finland	English	Retrospective	327	5	Wound	NA	ACDF	4
Seng et al. [72]	2013	Singapore	English	Prospective	64	2	Wound	CSM	ACDF	4
Anil et al. [79]	2014	America	English	Retrospective	1576	2	Wound	NA	ACDF	5
Dushyanth et al. [70]	2013	America	English	Retrospective	69	1	Wound	NA	NA	3
Basques et al. [100]	2015	America	English	Retrospective	151	1	Wound	NA	ACDF	4
Lei et al. [88]	2014	China	English	Retrospective	22	1	Wound	OPLL	NA	3
Li et al. [87]	2015	China	English	Retrospective	38	2	Epidural	NA	NA	3
Adamson et al. [101]	2016	America	English	Retrospective	1000	2	Wound	NA	ACDF	5
Boudissa et al. [97]	2016	France	English	Retrospective	2319	12	Epidural/wound	NA	NA	5

ACDF = anterior cervical decompression and fusion, ACCF = anterior cervical corpectomy and fusion, CSM = cervicalspondylotic myelopathy, OPLL = ossification of the posterior longitudinal ligament, RCT = Randomized Controlled Trial, NA = Not Applicable.

Table 2. Stratified meta-analysis of the prevalence of hematoma after anterior cervical spine surgery

Subgroups	No. of studies	No. of total patients	No. of hematoma	Pooled prevalence (%)	95% CI (%)	I^2 (%)	Q test *P* value
Total hematoma	95	34497	365	0.8	0.7-1.0	56.2	< 0.001
Hematoma type							
Wound	63	23449	258	1.0	0.7-1.2	59.8	< 0.001
Epidural	30	14292	79	0.4	0.3-0.5	0	0.479
Disease pattern							
CSM	14	2042	20	0.3	0-0.5	13.4	0.307
OPLL	5	119	5	4.2	0.6-7.8	0	1
Surgical type							
ACCF	7	619	10	0.4	-0.1-0.9	24.0	0.246
ACDF	16	6332	89	1.0	0.6-1.5	79.7	< 0.001
Language							
Chinese	61	22880	218	0.7	0.6-0.9	39.9	0.001
English	34	11617	147	1.1	0.8-1.4	70.9	< 0.001
Study design							
Retrospective	88	33578	352	0.8	0.7-1.0	58.2	< 0.001
Prospective	5	714	11	1.4	0.5-2.3	0	0.916
RCT	2	205	2	1.0	0-2.3	0	0.972
Country							
China	69	22461	216	0.7	0.6-0.9	36.4	0.002
America	12	7744	105	1.0	0.5-1.5	87.0	< 0.001
France	2	2345	13	0.5	0.2-0.8	0	0.378
Germany	3	636	12	1.7	0.7-2.7	0	0.535
Norway	2	486	7	1.4	0.3-2.4	0	0.609

ACDF = anterior cervical decompression and fusion, ACCF = anterior cervical corpectomy and fusion, CSM = cervical spondylotic myelopathy, OPLL = ossification of the posterior longitudinal ligament, CI = confidence intervals, RCT = Randomized Controlled Trial.

showed that patients underwent ACDF had a higher prevalence estimate 1.0% (95% CI 0.6%-1.5%) than those underwent ACCF 0.4% (95% CI-0.1%-0.9%).

Country-related hematoma: As the data for other countries were few, only China, America, France, Germany and Norway were included and summarized in **Table 2**. The pooled analysis showed the prevalence of hematoma were 0.7% (95% CI 0.6%-0.9%), 1.0% (95% CI 0.5%-1.5%), 0.5% (95% CI 0.2%-0.8%), 1.7% (95% CI 0.7%-2.7%) and 1.4% (95% CI 0.3%-2.4%) respectively.

Language-related hematoma: The pooled analysis showed English studies reported a higher prevalence estimate 1.1% (95% CI 0.8%-1.4%) than those in Chinese 0.7% (95% CI 0.6%-0.9%).

Study design-related hematoma: For retrospective studies, prospective studies and RCT, the prevalence of hematoma were 0.8% (95% CI 0.7%-1.0%), 1.4% (95% CI 0.5%-2.3%) and 1.0% (95% CI 0%-2.3%) respectively.

Sensitivity analysis

To confirm the stability of the meta-analysis, sensitivity analysis was performed by sequentially omitting individual eligible studies. The pooled prevalence was not materially changed after any single study was excluded which indicated the stability of the results.

Publication bias

For the prevalence of total hematoma meta-analysis, the Begg funnel plots showed no evidence of publication bias (z = 0.88, P = 0.378). The Egger test showed evidence of publication bias (t = -2.12, P = 0.045). For the prevalence of wound hematoma meta-analysis, the Begg funnel plots showed no evidence of publication bias (z = 0.15, P = 0.88). The Egger test showed

evidence of publication bias (t = -2.02, P = 0.06). For the prevalence of epidural hematoma meta-analysis, the Begg funnel plots showed no evidence of publication bias (z = 0.31, P = 0.754). The Egger test also showed no evidence of publication bias (t = 0.49, P = 0.639).

Discussion

Postoperative hematoma is reported as a rare and fatal early complication after anterior cervical spine surgery [33-45]. Current literature regarding hematoma following anterior cervical surgery is limited. A few case reports have described postoperative hematoma specifically and larger studies investigating overall complication rates have demonstrated the incidence of postoperative hematoma to be 0.1% to 9.9% [46-101]. However, the incidence of hematoma after anterior cervical spine surgery remains controversial. A meta-analysis based on 95 studies was performed to determine the incidence of postoperative hematoma. To the best of our knowledge, this is the first meta-analysis concerning hematoma after anterior cervical spine surgery.

The pooled data showed that the prevalence of total hematoma after anterior cervical spine surgery was 0.8%, the prevalence of wound hematoma was 1.0% and the prevalence of epidural hematoma was 0.4%. In summary, the incidence of total hematoma after anterior cervical spine surgery is low and the incidence of wound hematomais higher than epidural hematoma.

We did the subgroup analysis based on two common procedures of anterior cervical spine surgery. The pooled analysis showed that patients underwent ACDF had a higher prevalence estimate (1.0%) than those underwent ACCF (0.4%). Tyler Cole performed a MarketScan database analysis to identify 91,543 patients who underwent ACDF and 909 patients reported with postoperative hematoma. The incidence of postoperative hematoma after ACCF was 1.0% which the same with ours [102]. As ACDF is with smaller vision than ACCF, it is difficult to find small bleeding and risk of hematoma is high, which may explain the above-mentioned result.

Subgroup analysis was also performed based on two common cervical diseases which need anterior cervical spine surgery. The pooled analysis showed that patients with OPLL had a higher prevalence estimate (4.2%) than those with CSM (0.3%). For patients with OPLL, we need to remove the ossific ligament which may result in vertebral canal hemorrhage, the risk of hematoma will increase [57-60].

Subgroup analysis was also performed based on the country. In China, America, France, Germany and Norway subgroup, prevalence of hematoma was 0.5% (95% CI 0.4%-0.6%), 1.0% (95% CI 0.5%-1.5%), 0.5% (95% CI 0.2%-0.8%), 1.7% (95% CI 0.7%-2.7%) and 1.4% (95% CI 0.3%-2.4%) respectively. The pooled analysis showed that Germany is with a highest incidence of 1.7%. In our meta-analyses, there was substantial statistical heterogeneity and significant publication bias which may influence the result.

Although the incidence of postoperative hematoma is low, the consequences are serious or fatal and we should pay more attention to it. Qian reported the main causes of hematoma after anterior cervical spine surgery: presence of preoperative coagulopathy; intra operative hemostasis is not complete; and postoperative drainage is obstructed [41]. Kevin reported risk factors of retropharyngeal hematoma anterior cervical spine surgery to be: presence of diffuse idiopathic skeletal hyperostosis, presence of ossification of the posterior longitudinal ligament, therapeutic heparin use, longer operative time, and a greater number of surgical levels [78].

To prevent the occurrence of postoperative hematoma, several necessary measures should be taken. Specifically, all soft tissue and osseous bleeding should be controlled strictly during the operation [67-70]. Drainage tube should be placed correctly and maintain unobstructed [89]. Patients with coagulopathy should be given medical treatment before undergoing anterior cervical spine surgery [92-95]. Postoperative patients' vital signs should be monitored for 24-72 hours [96]. Once the patients showed symptoms of airway compromise or cord compression, evacuation of hematoma should be performed urgently [98-101].

Several potential limitations of this study should be carefully considered. Firstly, almost all of the included studies were not for the prevalence study design which may result in the impreciseness of the pooled data. Secondly, significant publication bias was observed in funnel plots. Thirdly, the diagnostic criteria of hematoma were not uniform among the included studies which may result in misdiagnosis of some potential cases.

Conclusions

In summary, the present studies observed a low incidence of hematoma after anterior cervical spine surgery. OPLL patients, ACDF surgery and Germany subgroup were associated with higher risk of hematoma. Considering the limitations noted above, a well-designed and multicenter study should be performed in the future.

Disclosure of conflict of interest

None.

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