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Risk Factors for Accidental Dural Tears in Spinal Surgery

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ABSTRACT

Background: Accidental dural tears (DTs) are familiar complications of spinal surgery. Their reported incidence varies widely, and several risk factors have been proposed in the literature. The aim of this study was to conduct a systematic review and meta-analysis to determine the rate of DTs and assess their associated risk factors.

Methods: A systematic literature search was conducted using specific MeSH and Text terms. Only articles with prospective data reporting the incidence and risk factors were selected and reviewed based on specific inclusion and exclusion criteria.

Results: Twenty-three studies were included. The reported incidence rate ranged from 0.4% to 15.8%, giving an overall pooled incidence rate of 5.8% (95% confidence interval [CI] 4.4–7.3). The incidence rate varied in relation to the part of the spine and the type of surgery. Three factors were associated with a high rate of DTs: age (overall mean difference of 3.04, 95% CI 2.49–3.60), revision surgery (overall odds ratio of 2.28, 95% CI 1.84–2.83), and lumbar stenosis (overall odds ratio of 2.03, 95% CI 1.50–2.75). Diabetes was weakly associated with DTs, with an odds ratio of 1.40 (95% CI 1.01–1.93). The overall effects of sex and obesity were not statistically significant.

Conclusion: Advancing age, revision surgery, and lumbar stenosis were significantly associated with increased risk of DTs. These factors should be taken into consideration during the consenting process for spinal surgery.

Clinical Relevance: Risk of dural tear during spine surgery.

Complications

Keywords: accidental dural tear, incidental dural tear, durotomy, spinal surgery, risk factors

INTRODUCTION

Accidental dural tears (DTs) are familiar complications of spinal surgery. They have been associated with neurological injuries[1] and poor outcome in some studies.[2] The reported incidence of DTs varied widely in the literature,[3] and several risk factors have been proposed.[3–6] Revision surgery is a risk factor that has been associated with DTs,[5–8] but the associations of other factors, such as sex, diabetes, and age, with DTs have not been consistent in the literature.[5,7] One reason for this could be the retrospective nature of many of the current published studies that are potentially blighted by bias, affecting the accuracy of the reported rates of DTs and their associated risk factors.

Therefore, the aim of this study was to carry out a systematic review of the literature to conduct a quantitative meta-analysis on the rate of DTs and their associated risk factors in elective spinal surgery. Only studies with prospectively collected data were included in this meta-analysis, and the following commonly reported risk factors were assessed: revision surgery, diagnosis (lumbar stenosis and lumbar disc herniation), age, sex, body mass index (BMI), and diabetes.

METHODS

A systematic literature search was conducted as part of a comprehensive project looking at the treatment and outcome of DTs in elective spinal surgery.[9,10] The method of the systematic literature search and MeSH terms used were reported in previous publications.[9,10] Briefly, this was conducted in Embase, Cochrane, Medline, and PubMed from inception until the end of January 2019. The identification and selection process of the studies followed the PRISMA flow chart (Figure 1). The details of all identified titles were downloaded into an Excel spread sheet, which facilitated the exclusion of duplicates, foreign language, case reports, and conference abstracts. The remaining titles and abstracts were reviewed, and any article that included any reference to incidental (iatrogenic or accidental) DTs (or ambiguous articles) was initially selected for further review. Full manuscripts for the

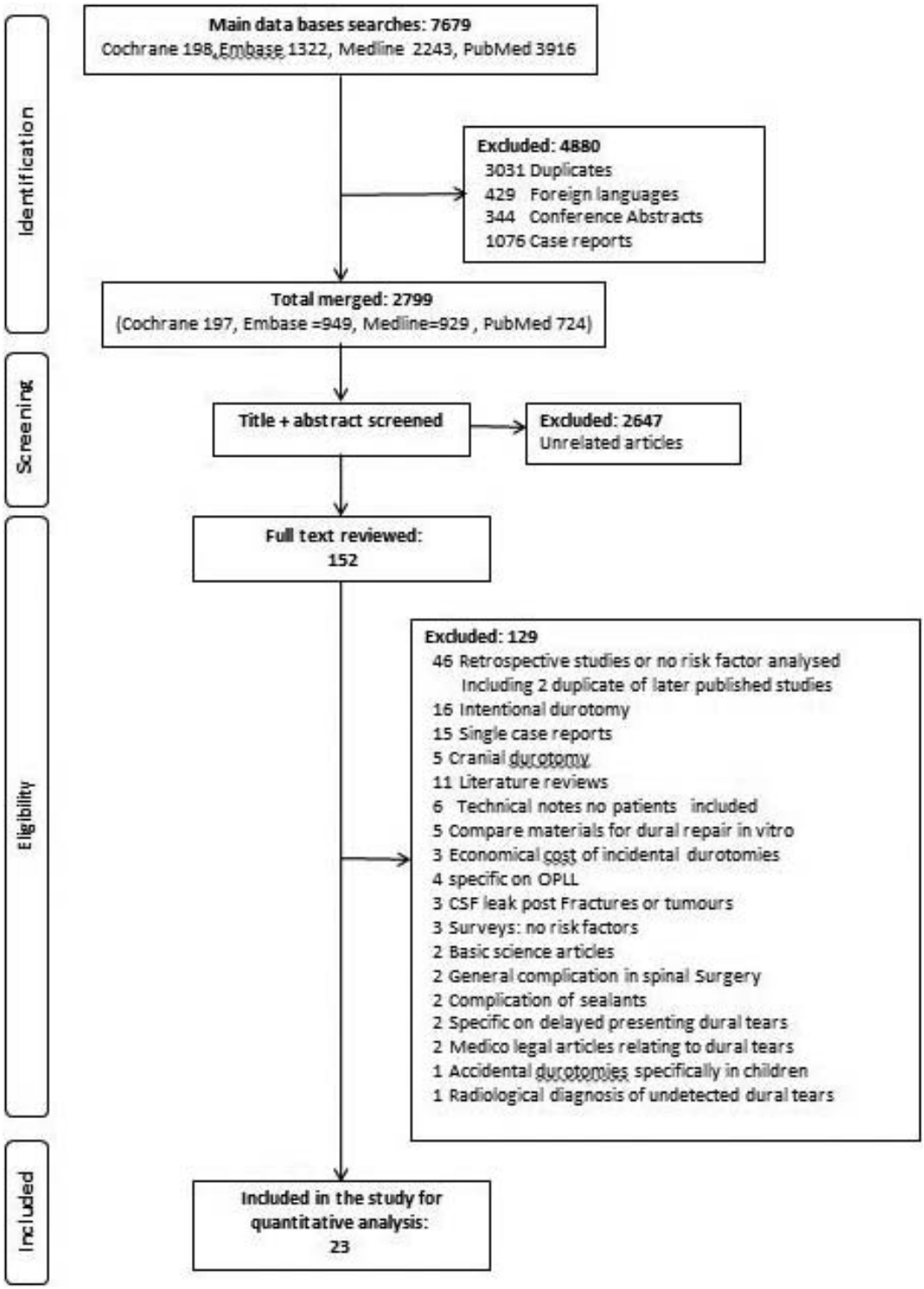

Figure 1. PRISMA flow chart demonstrating the selection process of the studies on risk factors for dural tears in spinal surgery. CSF, cerebrospinal fluid leak; OPLL, ossification of the posterior longitudinal ligament.

selected articles were then retrieved and reviewed for final inclusion. An up-to-date search covering the period from January 2019 to January 2020 was conducted, but none of the new articles met the inclusion criteria for this meta-analysis.

Assessing Study Eligibility

Only studies with prospective collection of the original data (especially patients' baseline characteristics) were included. Studies with retrospective

Table 1. Inclusion and exclusion criteria.

Inclusion Criteria
1. Articles on unintended (incidental, accidental, iatrogenic) dural tears (DTs) in elective spinal surgery in adults.
2. Prospective collection of original data.
3. The study has to mention and compare the frequency of incidental DTs in their cohort of patients with at least one of the following risk factors: age, revision (reoperation) surgery, diagnosis (lumbar disc herniation and lumbar stenosis), sex, and body mass index (BMI) (obesity).
4. English language articles.
5. Human participants.
6. Case series, case control, cohort, and randomized control trials were eligible to be included if they fulfilled the above criteria.
Exclusion Criteria
1. Studies with retrospective collection of baseline data or those that did not mention the time of data collection.
2. Individual case reports, abstracts, and articles in languages other than English.
3. Articles specifically dealing with ossification of the posterior longitudinal ligament.
4. Studies based on data from insurance companies' databases.
5. Dural tears from fractures, tumors, or intentional durotomies.

analysis of prospectively collected data, such as nested case control studies (from prospective cohort studies) or studies based on national registries or hospital databases with prospectively collected data, were also included. The inclusion and exclusion criteria are shown in Table 1.

Assessing Study Quality

The types and quality scores of each study identified are presented in Table 2. Most were nonrandomized control trials, and the Newcastle-Ottawa quality assessment scale[31] was used to assess the quality. This particular scale awards different numbers of stars based on three different categories: selection (maximum 4 stars), comparability (maximum 2 stars), and outcome (maximum 3 stars). This scale awards 1 star for controlling for factors during comparability, and therefore a star was awarded for multivariate analysis on multiple factors. Patients' responses and follow-up were irrelevant in this situation because all of the risk factors were based on patients' baseline characteristics. Therefore, the outcome score was awarded based on the original aim of each study.

Extraction of the Data

Data extraction was done according to a predetermined pro forma. Information on the type of study, the data source, the type and size of the cohort, and the risk factors covered were gathered and are presented in Tables 2 and 3.

The type of data extracted depended on the risk factor. Most articles with data on age reported the mean, the standard deviation (SD), and the sample size for patients with and without DTs. Hence, for the few articles that presented data on age but lacked some of these details, the authors were contacted to provide the mean and SD for their cohorts. When authors did not respond, the articles with missing details were excluded.

Articles with data on BMI reported their data as either categorical or continuous (mean and SD). For articles with categorical data, the cohorts were divided into two categories (BMI $>$ 30 and BMI $<$ 30) in accordance with the World Health Organization's definition of obesity,[32] and the overall odds ratio of DTs in obese patients was calculated. For articles with continuous data, the mean difference in BMI was calculated.

For the rest of the risk factors (diagnosis, revision surgery, diabetes, and sex), the number of patients with each risk factor in both cohorts (DTs and no DTs) was extracted from all articles that contained data on these risk factors. There were 3 separate studies from the SPORT trials all reporting the outcome of incidental DTs in disc herniation (discectomy),[14] lumbar stenosis,[23] and spondylolisthesis.[17] The data from two studies[14,23] were directly compared in the meta-analysis.

Data Synthesis

Meta-analysis calculations were conducted using the Review Manager 5 software (Cochrane collaboration).

For age and BMI (continuous data), the pooled weighted mean difference was calculated using the inverse variance and the random effect model. For categorical data (BMI, sex, revision, and diabetes), we calculated the overall weighted odds ratios based on the actual number of patients with and without DTs. The inverse variance and random effect model was also used to calculate the weighted difference and pooling of the overall odds ratio.

We examined heterogeneity using tau-squared and χ^2 tests. The I^2 statistic was used as an estimate for the total variation across studies owing to heterogeneity. To assess publication bias and outliers, a funnel plot was plotted for each risk factor.

The overall risk of DTs and the risk of DTs in different regions of the spine or in association with each factor was calculated using meta-analysis of

Table 2. Description and the quality of the studies as assessed by the Newcastle-Ottawa quality assessment scale.

Author	Study Type	Description	Data Source	Newcastle-Ottawa Quality Assessment Scale			Notes
				Selection	Comparability	Exposure/ Outcome	
Tafazal 2005[11]	Survey	Survey of members of the British Association of Spine Surgeons (BASS). Only the prospectively collected data provided by the members in the survey were included in the analysis. The cohort included primary and revision discectomy and lumbar stenosis.	Data from participants in the survey	NA	NA	NA	
Sin 2006[12]	Cohort	A comparison of prospectively collected data assessing the risk of DTs in patients who underwent surgery for lumbar degenerative disease (primary and revision discectomy and laminectomy).	Direct	4	0	2	
Williams et al 2011[13]	Case control	Analysis of a large case series from the Scoliosis Research Society assessing the incidence of DTs in a large cohort of patients including degenerative spine, trauma, scoliosis (in children), and deformity. Compared the incidence of DTs in different cohorts.	Registry	3	0	2	Only data on degenerative spine were included
Desai 2011[14]	Nested case control study	Nested case control study of patients that sustained DTs from the Spine Patient Outcomes Research Trial (SPORT) looking at the outcome of patients who underwent standard, first-time open discectomy	Direct	4	0	2	
McMahon 2012[1]	Case control study	Retrospective review of prospectively collected data from a hospital database looking at risk factors and outcome of DTs in spinal surgery (cervical, thoracic, and lumbar), including primary, revision, and MIS surgery.	Database	3	0	2	
Lotfinia 2012[15]	Case control study	A retrospective evaluation of prospectively collected data to assess the risk and frequency of DTs in patients who underwent elective lumbar spine surgery (primary and revision surgery) over a period of 2 years.	Direct	3	0	2	
Baker 2012[16]	Case control study	Retrospective analysis of prospective, multicenter registry data from a cohort of patients who underwent spinal surgery (whole spine including primary and revision surgery) looking at risk factors for DTs.	Registry	4	1	2	BMI was categorized
Desai 2012[17]	Nested case control study	Nested case control study of patients that sustained DTs from the SPORT looking at the outcome of DTs in patients who underwent standard first-time surgery for lumbar spondylolisthesis.	Direct	4	0	2	
Yoshihara 2013[18]	Case control studies	A retrospective analysis of data from the US national inpatient sample database for 2009 looking at the incidence and risk factors for DTs in patient who underwent primary lumbar discectomy or decompression.	Database	4	1	3	Scored 1 star in comparability for multivariate analysis
Tsutsumimoto 2014[19]	Cohort study	Analysis of data from a prospective study in consecutive patients undergoing microendoscopic lumbar decompression (MELD) surgery (METRx lumbar endoscopic system) at a single institution. They assessed the incidence and outcome of DTs in lumbar degenerative disease.	Direct	4	0	2	
Adogwa 2014[20]	Case control study	A retrospective analysis of prospectively collected data from a multi-institutional registry of patients who underwent primary lumbar fusion looking at the outcome of DTs.	Registry	3	0	2	

Table 2. Continued.

Author	Study Type	Description	Data Source	Newcastle-Ottawa Quality Assessment Scale			Notes
				Selection	Comparability	Exposure/ Outcome	
Yoshihara 2015[21]	Case control study	A retrospective analysis of data from the US national inpatient sample database for 2009 looking at incidental DTs in cervical spine surgery (primary and revision).	Database	3	1	2	
Smorgick 2015[22]	Cohort study	Analysis of prospectively collected data to assess the risk of DTs in patients who underwent lumbar spine surgery (primary and revision), including discectomy and laminectomy.	Direct	4	0	2	
Chen 2015[7]	Case control study	Retrospective analysis of a prospectively maintained hospital quality database of patients undergoing lumbar surgery (primary and revision), including discectomy and laminectomy.	Database	3	1	2	Scored 1 star in comparability for multivariate analysis
Desai 2015[23]	Nested case control study	Nested case control study on the outcome of durotomy in patients that sustained DTs from the SPORT involving patients who underwent standard first-time laminectomy with or without fusion for spinal stenosis.	Direct	4	0	2	
Ulrich 2016[24]	Nested case control study	Nested case control study from the Lumbar Stenosis Outcome Study (LSOS), a multicenter prospective cohort study looking at the outcome of DTs in patients who underwent primary lumbar surgery for lumbar stenosis.	Direct	4	0	2	
Murphy 2017[25]	Case control study	Retrospective analysis of data from a multicenter registry. Assessed risk factors for DTs in elective spinal surgery.	Registry	3	1	2	Scored 1 star in comparability for multivariate analysis
Herren 2017[6]	Case control study	Analysis of data from the Spine Tango registry. Assessed the incidence and risk factors for DTs in decompression for lumbar spinal stenosis (primary and revision surgery).	Registry	3	1	2	Scored 1 star in comparability for multivariate analysis
Ishikura 2017[26]	Cohort study	Analysis of a prospective, multicenter observational study on incidental durotomy and risk factors following spinal surgery in adult patients.	Direct	3	1	2	Scored 1 star in comparability for multivariate analysis
Kothe 2017[27]	Case control study	A retrospective analysis of prospectively collected multicenter registry data of patients who underwent lumbar surgery for lumbar stenosis looking at the outcome of DTs.	Registry	3	0	2	
Iyer 2018[28]	Case control study	A retrospective review of a prospectively collected multicenter adult deformity surgery database maintained by the International Spine Study Group. Assessed risk factors and outcome of DTs in primary and revision surgery.	Database	3	1	2	Scored 1 star in comparability for multivariate analysis
Stromqvist 2018[29]	Case control study	Analysis of data from the SweSpine, the national Swedish spine surgery register for degenerative lumbar surgeries (primary and revision), looking at risk factors and outcome.	Registry	3	0	2	
Takenaka 2019[30]	Cohort study l	Analysis of a prospectively observational multicenter study looking at DTs in primary degenerative lumbar spine surgery.	Direct	4	0	2	

Abbreviations: BMI, body mass index; DT, dural tear; MIS, minimally invasive surgery; NA, not available.

Table 3. Incidence of accidental dural tears and risk factors in each study included.

Author	Part of Spine	Surgery	*N* Total Cohort	*N* (%) Dural Tears	Available Data on Risk Factors for Meta-Analysis						Notes
					Age	Sex	Diagnosis	Revision	Diabetes	BMI	
Tafazal 2005[11]	Lumbar	Primary and revision	1549	93 (6.0)	No	No	Yes	Yes	No	No	Only prospectively collected data from the survey were used for this analysis.
Sin 2006[12]	Lumbar	Primary and revision	76	12 (15.8)	Yes	No	No	No	No	No	
Williams 2011[13]	Whole	Primary and revision	47 399	852 (1.8)	No	No	Yes	No	No	No	Only data on degenerative spine were included.
Desai 2011[14]	Lumbar	Primary	799	25 (3.1)	Yes	Yes	Yes	No	Yes	Yes	The diagnosis from this study was compared with Desai 2015[23].
McMahon 2012[1]	Whole	Primary and revision	3000	104 (3.5)	No	No	No	Yes	No	No	
Lotfinia 2012[15]	Lumbar	Primary and revision	1116	92 (8.2)	No	No	No	Yes	No	No	
Baker 2012[16]	Whole	Primary and revision	1591	161 (10.1)	Yes	Yes	No	Yes	Yes	Yes	BMI was categorized.
Desai 2012[17]	Lumbar	Primary	389	41 (10.5)	Yes	Yes	No	No	Yes	Yes	
Yoshihara 2013[18]	Lumbar	Primary	204 464	6819 (3.3)	Yes	Yes	Yes	No	Yes	Yes	Only data for diabetes were used from this study. Data for other risk factors obtained from a more recent update study (Yoshihara 2015[21]).
Tsutsumimoto 2014[19]	Lumbar	Primary and revision	555	28 (5.0)	No	Yes	Yes	Yes	No	No	Could not analyze for age as only odds ratio and mean with range were available, but no SD data were available.
Adogwa 2014[20]	Lumbar	Primary	1741	70 (4.0)	Yes	Yes	No	No	No	Yes	
Yoshihara 2015[21]	Cervical	Primary and revision	190 021	855 (0.4)	Yes	Yes	Yes	Yes	No	Yes	Age was categorized; therefore, it was not included in the analyses.
Smorgick 2015[22]	Lumbar	Primary and revision	523	55 (10.5)	Yes	No	Yes	Yes	No	No	
Chen 2015[7]	Lumbar	Primary and revision	2184	101 (4.6)	Yes	Yes	Yes	Yes	Yes	Yes	
Desai 2015[23]	Lumbar	Primary	409	37 (9.0)	Yes	Yes	Yes	No	Yes	Yes	The diagnosis from this study was compared with Desai 2011[14].
Ulrich 2016[24]	Lumbar	Primary	167	15 (9.0)	No	Yes	No	No	Yes	No	Only the median and IQR were presented for age; therefore, not included in the analysis.
Murphy 2017[25]	Whole	Primary and revision	104 930	655 (0.6)	No	Yes	No	No	Yes	Yes	BMI data were categorized. Age was not included because median and IQR were presented.
Herren 2017[6]	Lumbar	Primary and revision	3254	328 (10.1)	Yes	Yes	No	Yes	No	Yes	BMI data were categorized.
Ishikura 2017[26]	Whole	Primary and revision	4652	380 (8.2)	Yes	Yes	Yes	Yes	Yes	Yes	
Kothe 2017[27]	Lumbar	Primary and revision	800	67 (8.4)	Yes	Yes	No	Yes	No	Yes	
Iyer 2018[28]	Whole	Primary and revision	564	61 (10.8)	Yes	Yes	No	Yes	No	Yes	
Stromqvist 2018[29]	Lumbar	Primary and revision	64 431	3038 (4.7)	Yes	Yes	Yes	Yes	No	No	Categorized patients into 3 groups based on procedure and presented the data separately for each group.
Takenaka 2019[30]	Lumbar	Primary and revision	13 188	451 (3.4)	Yes	Yes	Yes	No	No	No	Authors kindly provided the SD for the data.

Abbreviations: BMI, body mass index; IQR, interquartile range; SD, standard deviation.

proportions[33,34] using the StatDirect software. The pooled proportions ranged from 0 to 1, corresponding with 0% to 100% respectively.

RESULTS

Twenty-three studies fulfilled our inclusion criteria[1,6,7,11–30] (Table 2). The number of studies evaluating different risk factors is presented in Table 3. William et al[13] reported a large case series from a registry database that included DTs from fractures and scoliosis in children as well as degenerative spine. Only data relating to the degenerative spine were included.

Quality of the Studies

The majority ($n = 18$) were case control studies including 4 nested case control studies, 3 from randomized control trials and 1 from a prospective cohort study. One survey contained prospectively collected data on the rate of DTs in revision and primary surgery.[11] Studies generally scored high in selection and outcome criteria on the Newcastle-Ottawa quality assessment scale (Table 2) because all of the risk factors were related to the baseline characteristics of participants.

The Incidence of Accidental DTs

Based on all of the studies included, the overall pooled proportion of DTs in the spine was 0.058 (95% confidence interval [CI] 0.044–0.073), corresponding to an incidence of 5.8% (95% CI 4.4–7.3). The overall proportion in the lumbar spine was higher than the overall average, 0.061 (95% CI 0.052–0.071) based on 17 studies. The overall proportion in the cervical spine was 0.017 (95% CI 0.009–0.027) based on 5 studies, and the overall proportion in the thoracic spine was 0.043 (95% CI 0.023–0.069) based on 4 studies.

Risk Factors

Age

Sixteen studies reported data on the age of patients (Table 3). Two studies[18,29] categorized their patients based on diagnosis. The data for the subgroups from these two studies were entered independently in the meta-analysis calculation but were also subsequently pooled and entered in a separate sensitivity analysis. There was an overall weighted mean difference of 3.04 years (95% CI 2.49–3.6, $P < .0001$) (ie, patients who sustained DTs were older [Figure 1]). The results remained the same following sensitivity analysis after pooling the data from the subgroups of patients from the 2 studies by Yoshihara et al[18] and Stromqvist et al[29] (Figure 2).

Sex

Eighteen studies reported data on the number of males and females in both groups (Table 3). The overall pooled proportion of DTs in males and females was the same, 0.06 (95% CI 0.040–0.074) and 0.06 (95% CI 0.041–0.076), respectively. Hence, the overall effect of sex on DTs was not significant, with an overall odds ratio of 1.04 (95% CI 0.093–1.15, $P = .52$) of sustaining DTs in females (Figure 3).

Diagnosis (Lumbar Stenosis versus Disc Herniation)

Ten studies provided details for the underlying diagnosis. The pooled proportion of DTs in lumbar stenosis was more than double that of discectomy, 0.055 (95% CI 0.034–0.081) and 0.027 (95% CI 0.017–0.040), respectively. Therefore, DTs in lumbar stenosis surgery were overall twice as likely to occur with an overall odds ratio of 2.03 (95% CI 1.50–2.75, $P < .00001$) relative to discectomy (Figure 4).

Revision Surgery

Thirteen studies provided data on revision surgery. The pooled adjusted proportion of DTs in revision surgery was more than double that in primary surgery, 0.118 (95% CI 0.072–0.175) and 0.054 (95% CI 0.031–0.083), respectively. Therefore, direct comparison revealed that DTs were twice as likely to occur in revision surgery, with an odds ratio of 2.28 (95% CI 1.84–2.83, $P < .0001$) (Figure 5).

Diabetes

Ten studies provided data on diabetes. The rate of DTs in diabetic and nondiabetic patients differed significantly among the studies, but there was only a small difference in the overall pooled proportion of DTs in diabetic and nondiabetic patients, 0.068 (95% CI 0.043–0.098) and 0.056 (95% CI 0.034–0.082), respectively. In direct comparison, there was an overall odds ratio of 1.40, barely reaching statistical significance (95% CI 1.01–1.93, $P = .04$) (Figure 6).

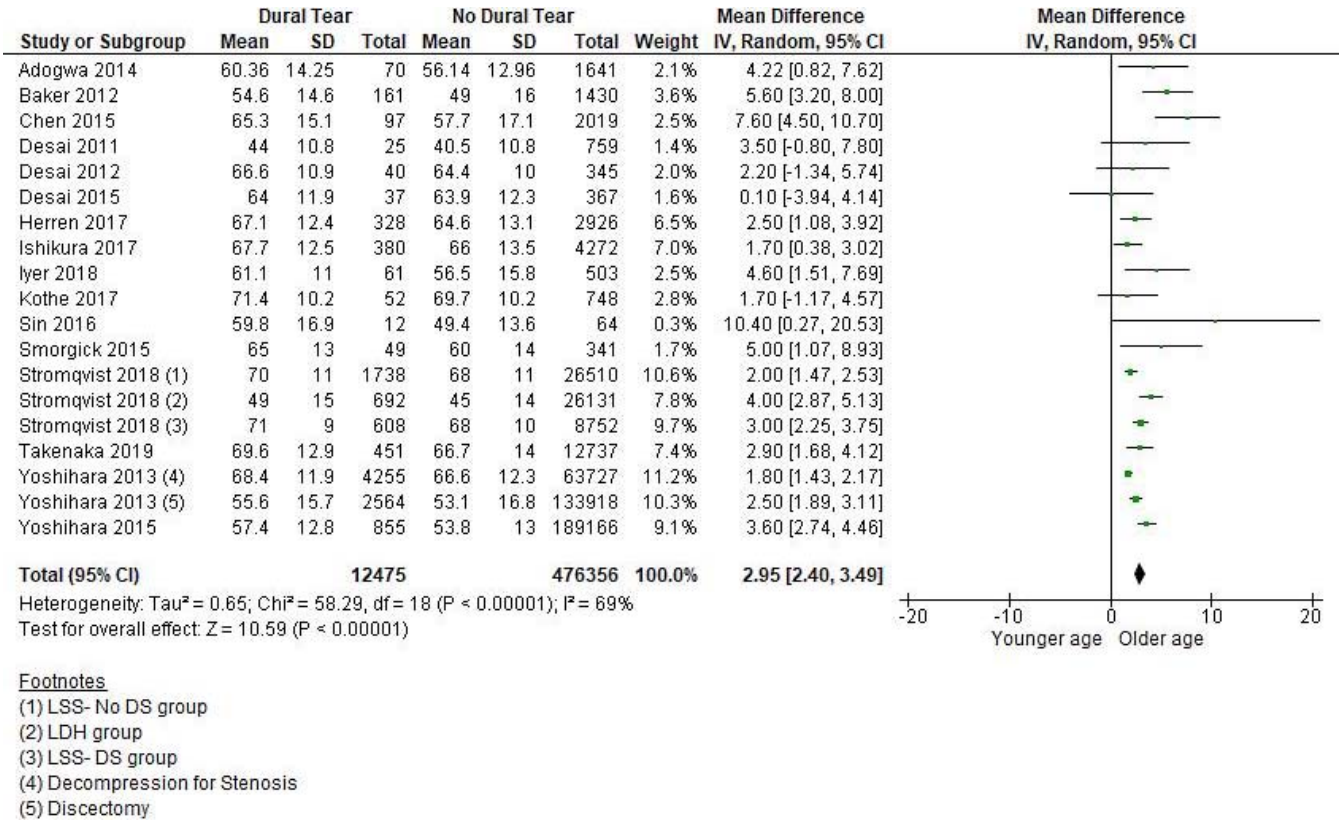

Figure 2. Forest plot depicting the overall difference in age between patients with and without dural tears. Data for the different categories from Stromqvist et al[29] and Yoshihara et al[21] were entered separately. DS, degenerative spondylolisthesis; LDH, lumbar disc herniation; LSS, lumbar spine stenosis.

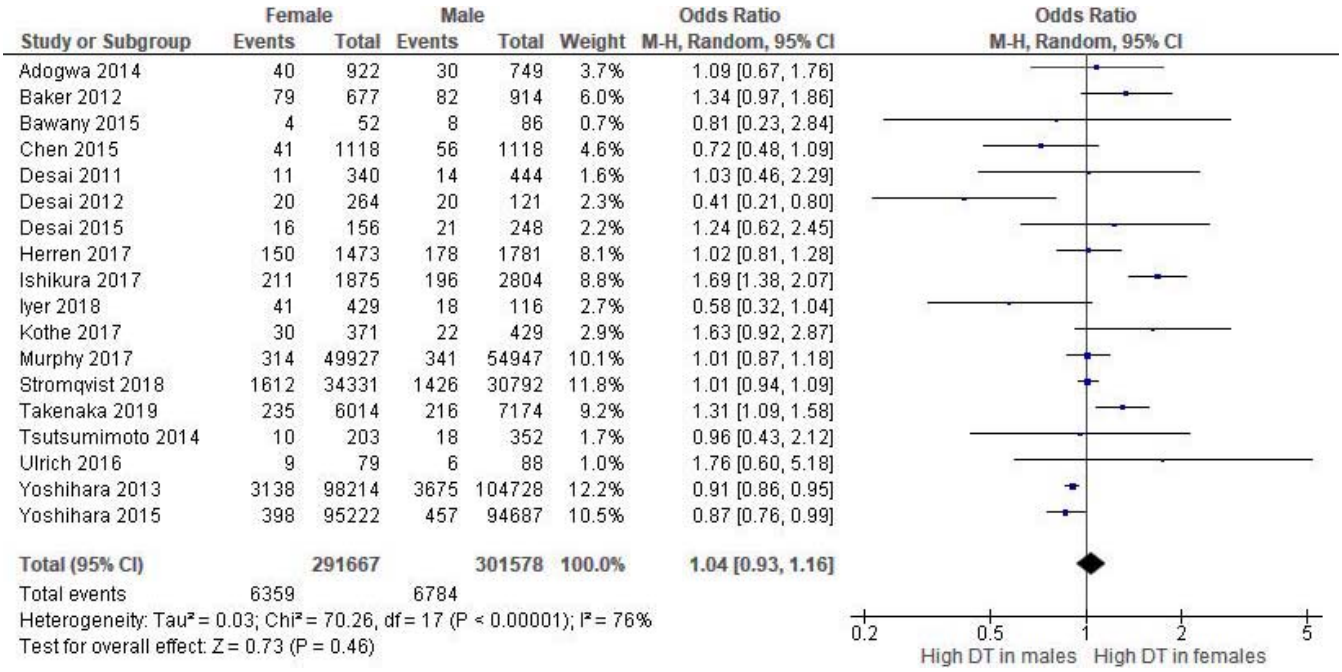

Figure 3. The overall odds ratios of DTs in females compared with males. DT, dural tear.

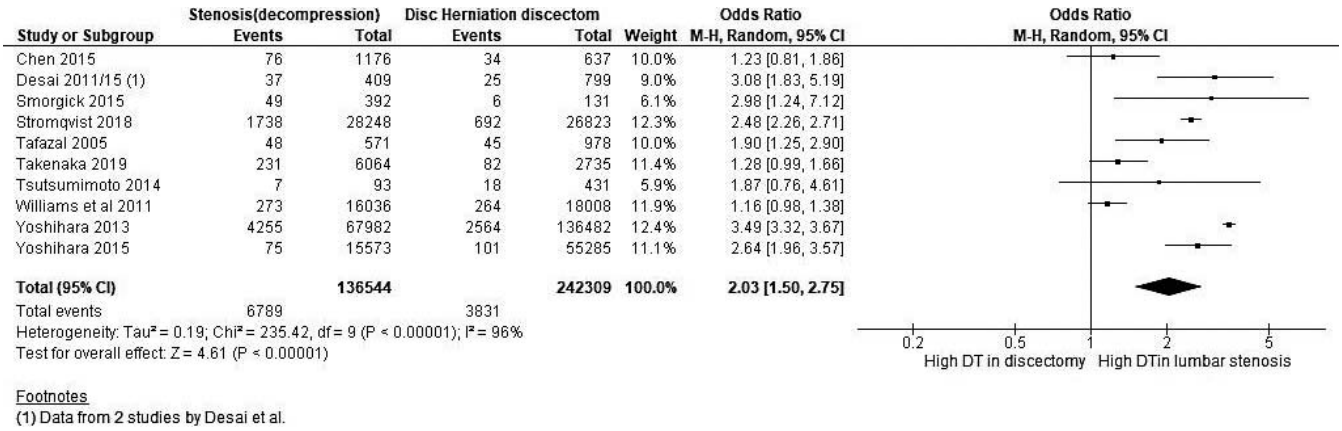

Figure 4. The odds ratio of sustaining DTs in lumbar decompression surgery versus discectomy. Desai et al 2011 (study on discectomy)[14] and Desai et al 2015 (study on lumbar decompression)[23] were entered as a single study as they were published from the same unit. DT, dural tear.

BMI

The overall weighted BMI mean difference in patients with and without DTs (in 8 studies) was not statistically significant, –0.45 (95% CI –1.43–0.54, $P = .38$) (Figure 7). Categorizing patients into obese (BMI $\geq$ 30) and nonobese (BMI $<$ 30) groups (in 6 studies) also did not show any significant difference, with an odds ratio of 1.14 (95% CI 0.97–1.35, $P = .12$); the proportion of DTs in obese and nonobese patients was 0.052 (95% CI 0.027–0.083) and 0.036 (95% CI 0.016–0.063), respectively (Figure 8).

Heterogeneity

The level of heterogeneity is reported with each forest plot. There was a high level of heterogeneity for all risk factors. Heterogeneity did not improve when excluding (or including) studies with similar characteristics, similar scores, or relate to the same region of the spine. Sensitivity analysis by excluding one study at a time for each risk factor did not lower the heterogeneity and did not identify a single study accountable for most of the heterogeneity. Heterogeneity only improved after excluding several studies for each risk factor, but the studies excluded

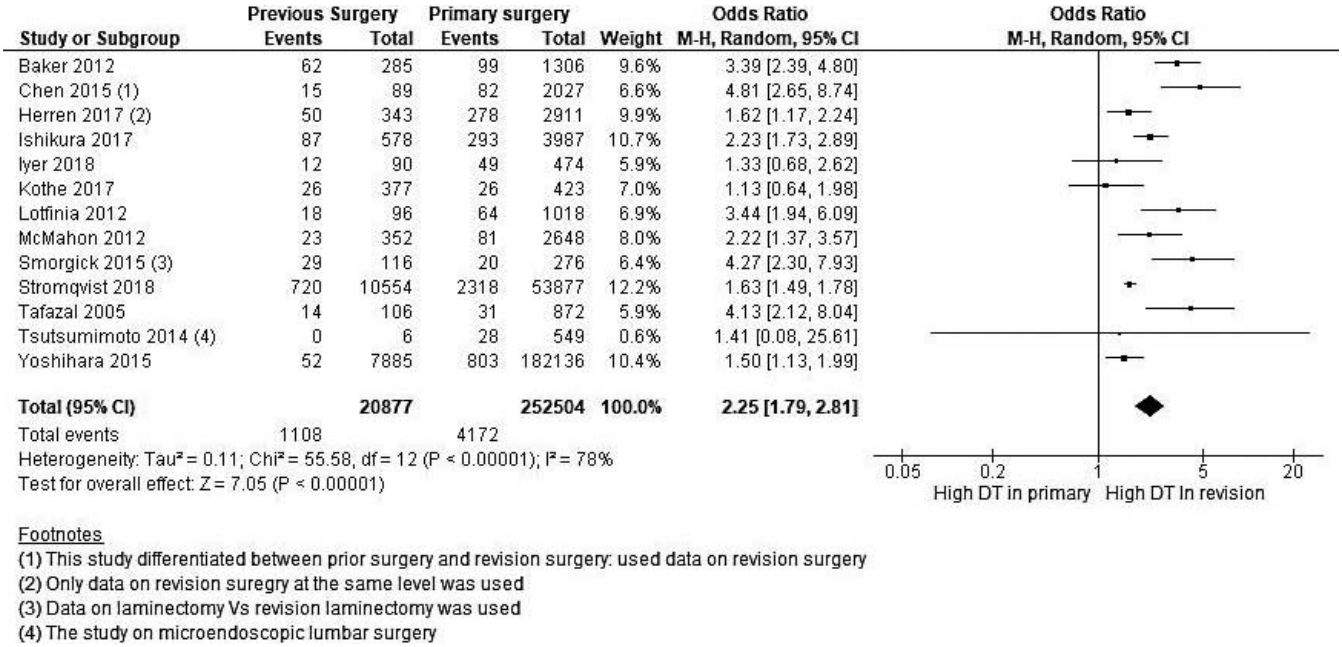

Figure 5. Dural tears in primary versus revision spinal surgery. Overall rate of DTs in revision spinal surgery with an overall odds ratio of 2.28 ($P < .00001$). DT, dural tear.

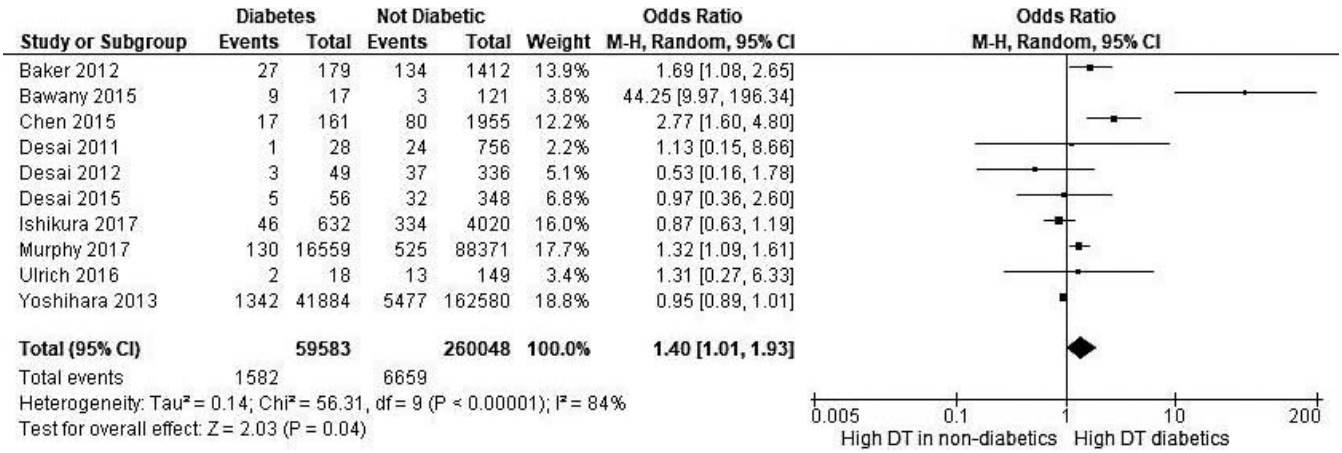

Figure 6. The overall odds of DTs in diabetic patients did not significantly differ from nondiabetic patients. DT, dural tear.

did not have any particular common factor. The plotted funnel plots did not reveal much asymmetry, and even after excluding the studies that appeared as outliers, heterogeneity did not significantly improve. Hence, it was decided to include all of the studies in our analysis in a random effect model regardless of the level of heterogeneity.

DISCUSSION

This systematic review and meta-analysis assessed six baseline characteristics of patients and their association with accidental DTs. We found that increasing age, revision surgery, and surgery for lumbar stenosis (as opposed to discectomy) were all associated with an increased rate of accidental DTs and, hence, could be considered as risk factors. Diabetes had a relatively weak association with DTs. Sex and high BMI (obesity) were not associated with an increased rate of DTs.

The overall incidence of accidental DTs significantly varied in the studies and ranged from 0.4% to 15.8%. A main factor that may explain this variation was the size of the cohorts reported by each study (Figure 9). Centers with a high number of surgical procedures reported lower rates of DTs and vice versa. This is consistent with what has been reported in a large registry study from different centers across Europe.[6]

The increased rate of DTs in revision surgery has been consistently reported in the literature in multivariate analyses in several studies.[3,5–7,16] This may be explained by factors such as scarring that predisposes to dural adhesions and loss of normal anatomical landmarks that increase the risk of DTs.

Similarly, age has also been shown to be an independent risk factor in both univariate and multivariate analyses.[3,5–7,16,18,21,35] With advancing age, there is a reduction in the strength and elasticity of the dural sac,[3] rendering the dura more delicate[36] and redundant (because of shortening of the spine by degeneration[18]) and becomes easily trapped by the tongs of the Kerrison rongeur.[18] Older patients are also more likely to have severe stenosis with thicker ligamentum flavum,[18,35] and, therefore, one might consider lumbar stenosis and age as covari-

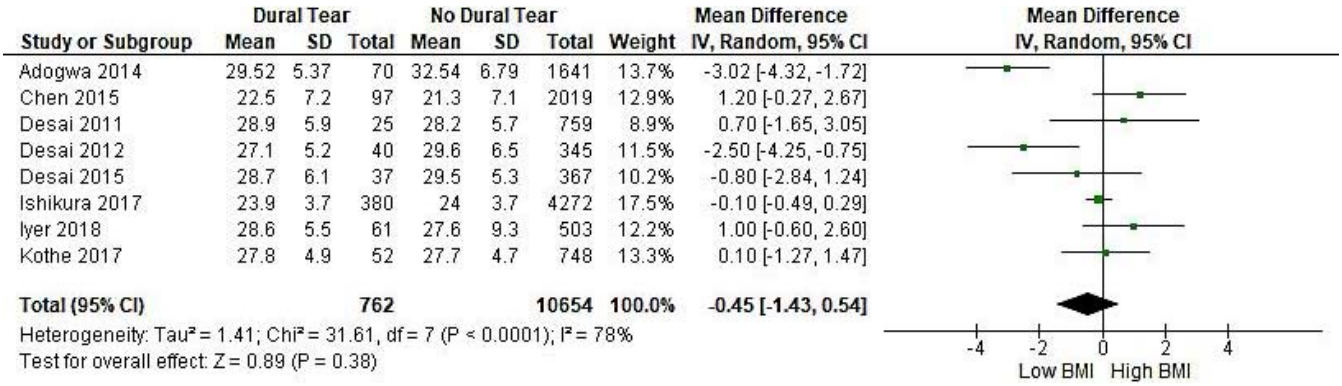

Figure 7. There was no overall difference in the mean body mass index (BMI) between patients with and without incidental DTs. DT, dural tear.

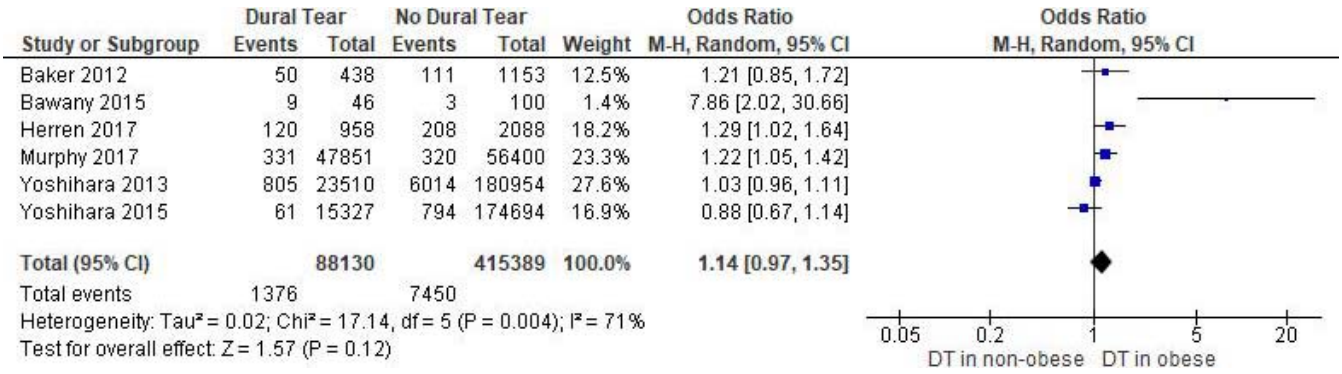

Figure 8. Forest plot with the overall odds of sustaining DTs in obese patients (body mass index [BMI] > 30). No significant difference was observed between obese and nonobese patients. DT, dural tear.

ates (or confounding) factors rather than independent risk factors. This is because in severe stenosis, there is further thinning of the dura that is more likely to be adherent to the thickened ligamentum flavum, which further increases the risk of DTs.[16] Furthermore, lumbar stenosis is mainly reported as a strong risk factor in univariate analysis and reached statistical significance in multivariate analysis in only a single study.[7]

Five of the studies reported diabetes as a significant risk factor on univariate analysis but failed to demonstrate the same significant results in multivariate analysis.[7,16,18,25,37] In our analysis, the overall odds ratio was low (1.4), with a lower confidence interval of almost 1 (95% CI 1.01–1.93), rendering it an almost insignificant risk factor. Although diabetes is commonly associated with other surgical complications, none of the studies have put forward a proposal explaining the association of diabetes with DTs. Similarly, 4 studies have associated obesity with DTs,[6,18,25,37] 2 on multivariate analysis,[6,25] but no explanation for this has been proposed. We propose that obesity can potentially render surgery technically more challenging and hence more likely predispose the dura to injury. The proportion of DTs was slightly higher in obese than nonobese patients, but the overall odds ratio in our meta-analysis did not reach statistical significance. It was not possible to combine all of the studies into one meta-analysis for obesity as the studies with categorical data were separately analyzed from those with continuous data. This might have diluted the data and reduced the overall power to detect any significant difference.

Two studies reported that females are at an increased risk for DTs on multivariate analysis,[18,21]

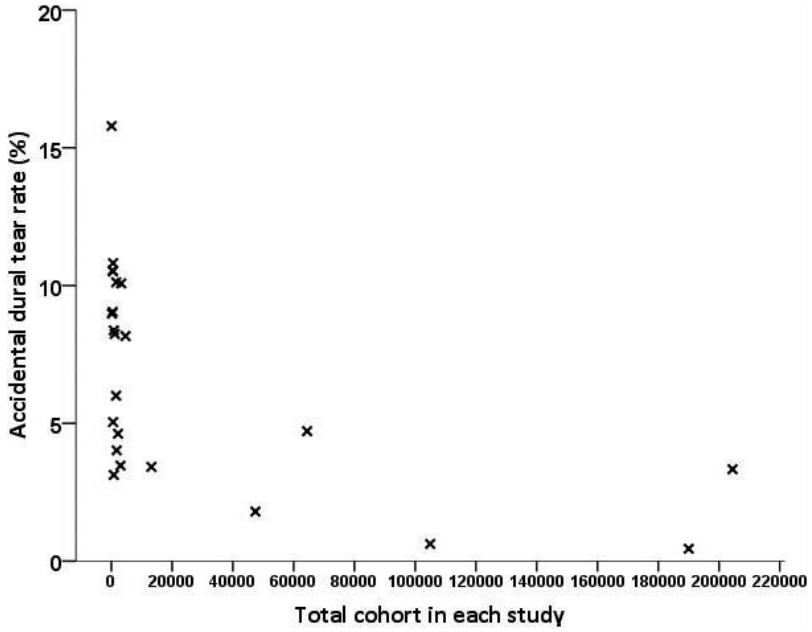

Figure 9. The rate of dural tears (DTs) in relation to the sample size included in the studies. Studies with small sample sizes reported high variation in the rate of incidental DTs. Low incidences of DTs were reported by studies with larger sample sizes.

but we could not demonstrate this in this meta-analysis. It has been postulated that the dural sac in females is thinner than in males,[38] and some have considered this as an explanation for the reported high risk of DTs in females.[26] However, this difference in dural thickness is not statistically significant[38,39] and, therefore, unlikely to account for the reported increased rate of DTs in females by some studies.

Data relating to risk factors were collected prospectively, and this bestows credibility to the data in these studies and to our meta-analysis results. Nevertheless, the quality of the studies included were all level 2 and 3 (cohort studies or case control) studies, and many were based on data from registries and hospital databases. This has resulted in publications with bigger sample sizes, conferring bigger weights to these studies, and heavily influenced the analysis for the overall effect. This could be one of the reasons why there was a high level of heterogeneity in the analysis. We have tried to ameliorate the impact of this by adopting a random effect model in our analysis, but we could not explain fully the reason for the high level of heterogeneity in our analysis.

In conclusion, revision surgery, age, and lumbar stenosis are risk factors for iatrogenic DTs in spinal surgery. These will need to be taken into consideration during the consenting process. The risk of diabetes was weak, and further studies are needed to address this.

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