Journal of King Saud University – Science 32 (2020) 2901–2904

Contents lists available at ScienceDirect

Journal of King Saud University – Science

journal homepage: www.sciencedirect.com

Original article

Predictors of surgical outcome in thoracic spinal stenosis: Focusing on cerebrospinal fluid leakage

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ARTICLE INFO

Article history:
Received 19 January 2020
Revised 1 April 2020
Accepted 9 April 2020
Available online 17 April 2020

Keywords:
Thoracic spinal stenosis
Cerebrospinal fluid leakage
Postoperative transient neurological deterioration
Surgical outcomes
Postoperative neurologic complications

ABSTRACT

The study was designed to investigate the effect of cerebrospinal fluid leakage (CFSL) on the surgical outcomes of thoracic spinal stenosis (TSS). 153 TSS cases were recruited for this study from January 2012 to December 2017. Preoperative duration of symptoms, neurological status, operative parameters, postoperative courses and neurological recovery were collected. Modified Japanese Orthopedic Association (JOA) score for thoracic myelopathy was used to assess neurological status, and recovery rate was calculated, accordingly. Comparison was between postoperative transient neurological deterioration (PTND) group and Non-PTND group. Cases were further grouped into favorable outcome (FO) (JOA recovery rate $\geq$25%) and unfavorable outcome (UO) (JOA recovery rate <25%) group, respectively. Further, multivariate logistic regression was performed to verify their relationships. Result showed that seventeen patients (11.1%) developed PTND, while sixty-seven patients (43.8%) developed CSFL. The mean JOA recovery rate was 58.2 ± 35.3%. The incidence of CSFL in PTND group was significantly lower than that in non-PTND group (17.65% vs 47.06%, $p = 0.02$). Multiple regression analysis showed that CSFL indicated a lower incidence of PTND (B = 1.608, $p = 0.03$). However, there was no significant difference between the incidence of CSFL in FO group and that of UO group (27.28% vs 46.56%, p = 0.09). In addition, preoperative duration of symptoms, preoperative JOA score and blood loss were associated with the surgical outcomes. The present study found that CSFL was associated with a lower risk of PTND in TSS, which has a certain guiding significance for clinical surgery.

1. Introduction

Thoracic spinal stenosis (TSS) is a relatively rare disease (Aizawa et al., 2007; Chen and Sun, 2015; Onishi et al., 2016; Wang et al., 2016). Due to its irreversible aggravating course and poor response to conservative treatment, surgeries are always the final option available (Miyakoshi et al., 2003; Takenaka et al., 2014; Chen and Sun, 2015; Portero et al., 2019; Muraoka et al., 2020; Misztal et al., 2020), although surgical outcomes are not always satisfactory. Cerebrospinal fluid leakage (CSFL) and postoperative transient neurological deterioration (PTND) are the two most common complications following surgeries (Hou et al., 2018; Xu et al., 2015). CSFL is reported to be related with a large number of complications such as meningitis, hematoma, hemorrhage, abscess fistulas, decreased intracranial pressure (Hu et al., 2016) and various other neurological complications, causing prolonged hospitalization and increasing risk of infection (Bosma et al., 2012), considering this, CSFL is regarded as a severe surgical complication in TSS surgeries (Orts-Del'Immagine et al., 2020; Ohata et al., 2019; Kotani et al., 2019; Miyan et al., 2019).

Interestingly, in clinical practice, patient with CSFL sometimes show a favorable surgical outcome in TSS. However, this remains controversial and less substantiated by currently exiting studies (Hu et al., 2016).

Therefore, this study was conducted to evaluate the relationship between CSFL and the surgical outcomes of TSS. The study further investigated other factors related to surgical outcomes in patients with TSS.

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.jksus.2020.04.008

1018-3647/

2. Methods

2.1. Subject recruitment

The study was advertised locally at the Department of Orthopedics, Peking University Third Hospital, China. Patients who responded to the advert were selected for the study. Patients who responded were informed about the scope, aim and objectives of the study. Patients were given consent form to fill and submit in two days' time. Those who submitted the form (153 patients) were selected and recruited for the study after passing all criteria. The number of male and female patients in the study were 79 and 74, respectively. The mean age was 51.4 ± 12.3 years. Approval from the Institutional Review Board (IRB) was obtained and the guidelines stated was adhered to throughout the duration of the study.

Inclusion criteria included absence of alcohol, absence of tobacco, absence of pregnancy (females only), patients included had stable conditions, language understanding, and not being diagnosed with any other severe systemically disease.

2.2. Study design

The surgical data were recorded, including preoperative duration of symptoms and Japanese Orthopedic Association (JOA) score, operative segments, operation duration, blood loss, postoperative neurological recovery, CSFL and recovery rate at the last follow-up. Patients were divided into PTND and Non-PTND groups according to the postoperative neurological recovery. In addition, patients were divided into favorable outcome (FO) and unfavorable outcome (UO) groups. We defined that the JOA recovery rate at the last follow-up that is greater than or equal to 25% for FO and less than 25% for UO group.

2.3. Statistical analysis

SPSS 22.0 for Windows (SPSS Inc., Chicago, IL, USA) was used to perform statistical analysis. Student unpaired T-test was used to analyze the difference of age at operation, preoperative duration of symptoms, operative segments, operation duration, blood loss, CSFL and preoperative JOA score between the PTND and non-PTND group, to determine the potential clinical predicting factors for PTND. The same analysis was also performed for the FO and UO groups to determine the potentials predictors for the long-term prognosis. Multivariate logistic regression analysis was also performed by using logistic stepwise regression model to fit PTND incidence.

3. Results

3.1. Mean JOA score

The mean JOA scores of the cohort were 5 ± 2.5 and 8 ± 2.5 for the preoperative and the last follow up, respectively. The mean JOA recovery rate was 58.2 ± 35.3%. On the other hand, the mean follow-up period for patients was 43.9 months. 17 patients (11.1%) developed PTND and 67 patients (43.8%) developed CSFL. The mean values for the other parameters were 30.8 ± 54.9 months for preoperative duration of symptoms, 3.7 ± 1.5 for the operative segments, 152.7 ± 69.3 min for the operation duration and 743.8 ± 833.1 ml for the blood loss.

3.2. Comparison between PTND and Non-PTND groups

The incidence of CSFL was different between the PTND and Non-PTND groups (p = 0.02). PTND group had a lower incidence of CSFL than Non-PTND group. There was also a significant (p = 0.02) difference between groups for the preoperative duration of symptoms, blood loss (p = 0.01), and preoperative JOA scores (p = 0.01), with a worse performance for the PTND group. However, no significant difference was found for age (p = 0.74), gender (p = 0.25), operation duration (p = 0.62) and operative segments (p = 0.10). (Table 1).

3.3. Comparison between FO and UO groups

The incidence of CSFL showed no significant difference between FO and UO groups (p = 0.09). While the preoperative duration of symptoms (p = 0.04) and preoperative JOA Scores (p = 0.03) exhibited a significant difference across the two groups, with worse performance for the UO group. No significant difference was found for age (p = 0.31), gender (p = 0.45), blood loss (p = 0.19), operation duration (p = 0.89) and operative segments (p = 0.42) between the two groups, as shown in Table 2 below

3.4. Risk factors for the development of PTND

The multivariate logistic regression analysis showed that CSFL was correlated with a lower incidence of PTND (OR = 4.994, 95% CI: 1.132–22.036). In addition, the study also showed that preoperative JOA score was positively associated with a lower incidence of PTND (OR = 0.672, 95% CI: 0.516–0.876) (Table 3).

4. Discussion

TSS is a rare spinal disorder. Considering its progressive nature, surgery is indicated upon the diagnosis (Garry, 2018). A large number of complications may occur after surgical decompression of TSS. Some risk factors were reported to affect surgical neurological outcomes such as preoperative duration of symptoms and preoperative JOA score (Garry, 2018). Previous reports have highlighted a list of complications after surgical decompression in TSS patients, in which the most common one is CSFL (Ando et al., 2013; Yu

Table 1
Comparison between postoperative transient neurological deterioration and non-postoperative transient neurological deterioration groups.

Clinical Factors	PTND (N = 17)	Non-PTND (N = 136)	P
Age (Year)	52.29 ± 11.67	51.26 ± 12.39	0.74
Gender (Male%)	64.71%	50.00%	0.25
Symptoms Course (Month)	59.47 ± 122.12	27.21 ± 38.83	0.02
Operative Segments	4.29 ± 1.69	3.64 ± 1.50	0.10
Operation Duration (Min)	160.65 ± 77.73	151.68 ± 68.37	0.62
Blood loss (ML)	1250.59 ± 1559.30	680.44 ± 675.99	0.01
CSFL	17.65%	47.06%	0.02
Preoperative JOA Score	3.24 ± 2.08	5.77 ± 2.43	0.01

Table 2
Comparison between favorable outcome and unfavorable outcome groups.

Variables	UO (N = 22)	FO (N = 131)	P
Age At Operation (Year)	53.82 ± 11.03	50.96 ± 12.47	0.31
Gender (Male%)	59.09%	50.38%	0.45
Symptoms Course (Month)	53.50 ± 100.10	26.98 ± 42.45	0.04
Operative Segments	3.95 ± 1.73	3.67 ± 1.50	0.42
Operation Duration (Min)	154.55 ± 76.07	152.36 ± 68.35	0.89
Blood Loss (ML)	958.64 ± 962.45	707.71 ± 807.97	0.19
CSFL	27.28%	46.56%	0.09
Preoperative JOA Score	4.41 ± 2.38	5.67 ± 2.50	0.03

Table 3
Risk factors for postoperative transient neurological deterioration by multivariate logistic regression analysis.

Variables	B	S.E.	OR	95% CI		*P*
Operative Time (Min)	0.007	0.004	1.007	1.000	1.015	0.05
Blood Loss (ML)	0.000	0.000	1.000	1.000	1.001	0.24
CSFL	1.608	0.757	4.994	1.132	22.036	0.03
Preoperative JOA Score	−0.397	0.135	0.672	0.516	0.876	0.01

et al., 2013; Zhang et al., 2016; Fang et al., 2017; Barber et al., 2019). However, there are very limited studies, specifically those exploring the correlation of CSFL and surgical outcomes of TSS patients but the result remains controversial (Bosma et al., 2012; Hu et al., 2016; Zhang et al., 2016; Fang et al., 2017; Garry, 2018; Barber et al., 2019; Ruan et al., 2019; Gu et al., 2019; Bhrini et al., 2020; Ruan et al., 2019; Pluim et al., 2019). This study investigates the effect of CSFL on the outcome of TSS and reports an interesting finding.

Result showed that there is a higher incidence of CSFL among Non-PTND group than that of PTND group (Non-PTND: 47.06% and PTND:17.65%), which indicates that CSFL may be relevant with a lower incidence of PTND. Although there are limited studies investigating the association between CSFL and PTND after TSS surgery, evidence shows that there is a positive effect of cerebrospinal fluid drainage (CSFD) on postoperative neurological recovery, and this is in line with report by Farhat et al. (2011) which proposed CFSD as a safe and alternative method to the classic lumbar cistern drain. Induced CSFD has been used to decrease the intraspinal pressure. Consequently, it can reduce the risk of postoperative neurological deterioration by increasing the blood flow to the spinal cord. Estrera et al. (2009), applied CSFD to treat thoracic aorta ailments with minimum neurologic deteriorations afterwards and reported a positive result. Similarly, Horn et al. (2008), studied the effects of lowered intrathecal pressure by CSFD, and observed the improved outcomes by performing it after acute spinal cord injury (Song et al., 2018; Donatelli et al., 2018; Sarbu et al., 2020). Furthermore, the observational study by Sugiura et al. (2017), showed that CSFD effectively prevented neurological dysfunction of spinal cord, demonstrating that maintaining the spinal cord perfusion pressure by utilizing CSFD is strongly associated with favorable neurological outcomes in patients undergoing spinal surgery. The potential mechanism for this result is that CSFL can reduce intraspinal pressure and consequently increase spinal cord perfusion pressure, which may reduce the risk of PTND. According to Mazzeffi et al. (2018), lowering the intrathecal pressure by induced CSFD can increase spinal cord perfusion pressure and decrease the risk of ischemic spinal cord injury by half. Similarly, Khan et al. (2016) reported that the use of CSFD to reduce intrathecal pressure can improve the spinal cord perfusion pressure and provide effective barrier against the incidence of paralysis or other neurologic deterioration. Furthermore, studies by Coselli et al. (2002), showed that the CSFD prior to the thoracic aortic occlusion can reduce the intrathecal pressure, increase the spinal profusion pressure, and decrease the incidence of paraplegia.

Generally, surgical procedures in cases with dural adhesion and dural ossification are performed with profound caution. There are some previous studies showing the thinning and floating of ossified adhesion in severe dural adhesion. However, the above operation can sometimes lead to residual compression and poor surgical outcome (Matsumoto et al., 2008; Liu et al., 2014). Hence, it is unnecessary for surgeons to worry about the negative effect of CSFL on neurological function. CSF flow through a dural defect and temporary subfascial CSF diversion which are currently being used, facilitates fascia time healing, following drain removal. The subfascial pressure and intrathecal pressure are believed to be equalize, leading to indirect slowing of CSF leakage and eventual secondary healing of the dural defect (Fang et al., 2016).

Result from this study also showed that CSFL cannot affect the long-term surgical outcomes for TSS, echoing to previous studies. A study suggested that CSFL after spinal surgery causes significantly higher health care costs but has only a trivial impact on the long term neurological recovery (Weaver et al., 2001). Similarly, Guerin et al. (2012) suggested that dural tears and cerebrospinal fluid leaks did not lead to any long-term significant sequelae for spinal surgery. A retrospective study by Cammisa et al. (2000) showed that incidental durotomy and CSFL, if recognized and treated appropriately, did not lead to long-term neurologic deficit.

This study also showed that longer preoperative duration of symptoms, lower preoperative JOA score and greater blood loss were the predictors for poor outcomes after TSS. These findings match the results of many other studies. Onishi et al. (2016), revealed that patients with a longer preoperative duration of symptoms, lower preoperative JOA score and greater blood loss experienced poor outcomes. Similarly, the minimum 2-year follow-up study in 132 patients by Aizawa et al. (2007), suggested that longer preoperative duration of symptoms and lower preoperative JOA score postoperative were risk factors for neurological deterioration. In addition, studies by Zuckerman et al. (2014), showed that large amount of intraoperative blood loss resulted in the decrease spinal cord perfusion pressure and spinal cord ischemia, which led to poor surgical outcomes. Therefore, those studies indicated that early detection, early treatment and minimize intraoperative bleeding are very necessary to improve the surgical outcomes for TSS. Findings from this study may provide new reference for the clinical practice and surgery planning.

5. Limitations

There are several limitations in this study. First, this is a single-center study and has a relatively small sample size. Also, the findings of this study is a challenge for previous clinical practical perspective, care must be taken for interpretation of findings. These limitations demonstrate that further study with a larger population from varying geographical source must be conducted.

6. Conclusion

In conclusion, it was discovered that some risk factors are associated with the surgical outcomes of TSS, including preoperative duration of symptoms, preoperative JOA score and blood loss. Besides, the findings of this study also found that CSFL may have a positive effect on postoperative neurological recovery after decompression surgery for TSS, which may provide new reference for clinical practice.

Authors contribution

Author WL and LX were responsible for the study design. WL, LX, LZJ, WF, JL, YM and LXG participated in the surgical decompression procedures and did the experimental follow-up of the samples. WL and LX performed all the data processing. WL wrote the manuscript. YM, JL and LXG revised the manuscript. All authors read and approved the final submitted manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

This work was supported by the National Natural Science Foundation of China (No: 81972103).

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