

# The risk factors of surgical site infection following posterior cervical spine surgery

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## Research article

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# Abstract

**Background:** Surgical site infection (SSI) is a common complication following posterior cervical spine surgery, imposing a high burden on patients and society. However, information about its characteristics and related risk factors is limited. We designed this study intended to address this issue.

**Methods:** From January 2011 through October 2020, a total of 405 patients diagnosed of cervical degenerative diseases (cervical spondylotic myelopathy, ossification of posterior longitudinal ligament and cervical disk herniation) who were treated with unilateral open-door lamnioplasty surgeries were enrolled in this study. We divided the patients into the SSI group and the non-SSI group and compared their patient-specific and procedure-specific factors. Univariate and multiple logistic regression analyses were performed to determine risk factors.

**Results:** There were significant differences between groups in subcutaneous fat thickness (FT) ( $P < 0.001$ ), ratio of subcutaneous FT to muscle thickness (MT) ( $P < 0.001$ ), preoperative Japanese Orthopaedic Association (JOA) Scores ( $P < 0.003$ ), preoperative serum albumin ( $P < 0.001$ ), postoperative drainage ( $P < 0.004$ ), time of draining ( $P < 0.001$ ). Logistic regression analysis of these differences showed that ratio of subcutaneous FT/MT, preoperative JOA score, preoperative serum albumin and longer time of draining were significantly related to SSI ( $P < 0.05$ ).

**Conclusion:** Ratio of subcutaneous FT/MT, preoperative JOA score, preoperative serum albumin and longer time of draining are identified as the independent risk factors of SSI in posterior cervical spine surgeries. Identification of these risk factors could be useful in reducing SSI incidence and patients counseling.

## Introduction

Surgical site infection (SSI) the most common complication after spinal surgery is an infection of the tissues, organs, or spaces exposed by surgeons during the performance of an invasive procedure<sup>1-3</sup>. SSI was classified as superficial, deep, or organ space. Compared with lumbar surgeries, cervical surgeries cases were associated with a significantly lower rate of infection<sup>4</sup>. Meanwhile, posterior cervical spine surgeries cases having a significantly higher rate of infection than anterior cervical surgeries cases with consequences ranging from superficial to deep infection<sup>5</sup>. The incidence of postoperative surgical site infections (SSIs) after posterior cervical spine surgeries is reported to range from 1.4–13%<sup>6,7</sup>. SSI leads to devastating outcomes including requires multiple readmissions, wound debridement or implant removal and increasing mortality, which results in readmission to the hospital, poor outcomes and additional hospitalization expenses causing patients' physical, mental, and economic burdens<sup>8-10</sup>.

Although advances have been made in infection control practices, the incidence of SSI after posterior cervical surgery ranges from 1.3–14%. Several risk factors for SSI in posterior cervical spine surgeries are increasingly being investigated. Many estimated risk factors have been reported in previous studies, such

as advanced age, higher body mass index (BMI > 30 kg/m<sup>2</sup>), smoking, diabetes, malnutrition (preoperative albumin level < 3.5 g/dL), history of infection in the surgical site, preoperative steroid therapy, blood loss, implant, and prolonged operative time (> 3 hours) <sup>11-16</sup>. Meanwhile, bacterial culture indicated that the most common causative microorganisms of SSI in spinal surgery are *Staphylococcus aureus* and other members of *Staphylococcus* species<sup>17,18</sup>. However, the results in these previous studies were not always consistent and there were few studies about the risk factors of SSI following posterior cervical spine surgeries. In this study, we investigated the frequency of SSI and evaluated the risk factors for SSI in a Chinese population by comparing patient-related and procedure-related factors to identify cases of SSI and determine the factors that modify the risk of SSI to relief the burden on society.

## Materials And Methods

### Patient Population

This was a retrospective clinical study. From January 2011 to October 2020, 435 patients following posterior cervical spine surgeries at First Affiliated Hospital of Dalian Medical University and were included in this study and were observed for a minimum of 2 months postoperatively. 30 patients in this experiment were lost to follow-up among them. Information gathered included demographic details, cause of disorder, diagnosis, radiologic findings, and laboratory investigations. Preoperative, intraoperative, and postoperative findings were recorded. All patients aged 18 years or older who had cervical degenerative diseases (cervical spondylotic myelopathy, ossification of posterior longitudinal ligament and cervical disk herniation) treated by unilateral open-door lamnioplasty surgeries were included. The exclusion criteria were as follows: age < 18 years, traumatic fractures, and pathologic fractures (metastasis, tuberculosis) and 405 patients were enrolled. All surgical procedures were performed in operating rooms equipped with vertical laminar air flow. All surgical personnel wore body exhaust suits. We administered antibiotic prophylaxis just before surgery and 72 hours postoperatively for all patients. Each patient in the study underwent classic open-door lamnioplasty surgeries. A deep one-off negative pressure drain was inserted, and the fascia was closed meticulously, followed by closure of the wound. The drain was removed about 2 days postoperatively when the discharge was observed to be < 50 ml. The postoperative rehabilitation protocols were similar in all patients.

### Identification of SSI

The diagnosis of SSI involves the interpretation of combined clinical, laboratory, and occasionally radiologic findings. SSI is considered as a diagnosis within 30 days of surgery in the absence of implants, and up to 1 year postoperatively in the presence of surgical implants. In this study, the definition of SSI was based on the Centers for Disease Control and Prevention definition. Superficial infection involves the skin and subcutaneous tissue only, occurring within 30 days after the operation, leading to pain, tenderness, redness, and heat over the site. Deep infection involves the fascia and muscle, occurring within 30 days after the operation (if no implant was left in place) or within 1 year (if the implant was left in place), often resulting in fever (> 38°C), pain, tenderness, and abscess formation. Organ infection includes septic discitis, vertebral osteomyelitis, and epidural abscess, leading to possible purulent

drainage and abscess formation<sup>1</sup>. The microbiological culture results from all patients who experienced SSI were collected and recorded. In patients who underwent open debridement, microbiological cultures were taken to confirm the presence of SSI and to decide further treatment.

### **Data collection and outcome evaluations**

The patients were divided into an SSI group and a non-SSI group in this study. We compared their patient-related factors such as: age, gender, BMI, muscle thickness(MT), subcutaneous fat thickness(FT), diabetes mellitus(DM), hypertension, ischemic heart disease, steroid use, rheumatoid arthritis, preoperative Japanese Orthopaedic Association(JOA)Scores, previous SSI, other infections such as pulmonary infection, urinary infection, and so on during the perioperative period, preoperative American Society of Anesthesiologists score, preoperative Visual Analogue Scale, preoperative temperature, preoperative white blood cell count, preoperative hematocrit, preoperative and postoperative hemoglobin, preoperative total lymphocyte count, preoperative serum albumin) and procedure-related factors (operative time, operated levels, estimated blood loss, postoperative drainage, time of draining, allogeneic blood transfusion, intraoperative rapid sterilizer use, local intrawound vancomycin antibiotic powder, dural tear, perioperative invasive vascular catheterization, postoperative prophylactic antibiotics).

### **Statistical Analysis**

The mean and standard deviation were calculated for continuous variables; number and percentage were calculated for categorical variables. Firstly, a univariate logistic regression analysis was performed to evaluate the relationship between each categorical variable and SSI. The t-test or Mann-Whitney U test was used for continuous variables, depending on the data distribution (equal variance and normality or not). A P value < 0.05 was considered to be significant. Further, all the related variables were entered into the multivariate logistic regression model to determine the independent risk factors for SSI.

## **Results**

The total incidence of SSI after posterior cervical spine surgery was 4.93% (20/405). The SSI group was composed of 11 men and 9 women, whose ages ranged from 55 to 73 years (median, 65 years). The non-SSI group was composed of 232 men and 153 women, whose ages ranged from 40 to 79 years (median, 61 years). Of the 20 patients with SSI cases, superficial in 15 and deep in 5 were treated with not only prolonging the use of antibiotics but also surgical debridement and VSD covered. All patients recovered well and with no implants removed.

Univariate analysis of patient demographics revealed several significant predictors of SSI including patient-related risk factors, procedure-related risk factors, and perioperative factors. Several medical comorbidities were associated with SSI rates including FT, Ratio of Subcutaneous FT to MT, preoperative JOA, preoperative serum albumin. Notable factors that were not predictive of SSI included diabetes mellitus, smoking, Gender, Age, BMI, MT and so are summarized in (Table 1). Univariate and multiple logistic regression analyses were used to evaluate the effect of each factor on the SSI (Table 2). Univariate logistic regression analysis showed that subcutaneous FT, Ratio of Subcutaneous FT to MT,

preoperative JOA, preoperative serum albumin, postoperative drainage, time of draining were significant risk factors for SSI ( $P < 0.05$ ). Multivariable logistic regression analysis identified four positive independent predictors of SSI including Ratio of Subcutaneous FT to MT, preoperative JOA, preoperative serum albumin, time of draining. Previous studies of risk factors for SSI in Posterior cervical spine surgery on Table 3.

Table 1  
Risk Factors for SSI in Posterior Cervical Spine Surgery Using Univariate Analysis

Variable	SSI Group (n = 20)	Non-SSI Group (n = 385)	p value
Gender	9:11	153:232	0.640
Age	61.160	63.500	0.098
BMI	26.140	26.435	0.187
MT	36.880	36.950	0.714
FT	23.730	32.150	< 0.01
Radio of FT/MT	0.878	0.647	< 0.01
Smoking	6.000	121.000	0.893
Alcohol	3.000	67.000	1.000
DM	5.000	80.000	0.865
Hypertension	5.000	92.000	1.000
Ischemic heart disease	2.000	40.000	1.000
Rheumatoid arthritis	6.000	64.000	0.215
Chronic steroid usage	3.000	53.000	1.000
Previous SSI	2.000	36.000	1.000
ASA score	2.020	2.200	0.354
VAS score	7.249	7.300	0.924
Preoperative JOA score	7.618	5.850	< 0.01
Preoperative temperature	36.476	36.485	0.744
Preoperative white blood cells	7.487	7.493	0.699
Preoperative hematocrit	43.103	42.070	0.326
Preoperative total lymphocyte count, 10 <sup>9</sup> /L	1.918	1.965	0.589
Preoperative hemoglobin	136.647	136.150	0.967
Postoperative hemoglobin	107.239	103.150	0.377
Preoperative serum albumin (g/dL)	42.061	35.075	< 0.01

BMI, body mass index; MT, muscle thickness; FT, fat thickness; DM, diabetes mellitus; SSI, surgical site infection; ASA, American Society of Anesthesiologists; VAS, Visual Analogue Scale; JOA, Japanese Orthopaedic Association.

Variable	SSI Group (n = 20)	Non-SSI Group (n = 385)	p value
Operative time, minutes	140.234	142.000	0.441
Operated levels	3.722	3.800	0.447
Estimated blood loss, mL	430.208	435.000	0.129
Postoperative drainage, mL	269.325	406.500	0.005
Time of draining, hours	48.696	62.400	< 0.01
Perioperative invasive vascular catheterization	7.000	132.000	0.948
Intraoperative rapid sterilizer use	1.000	17.000	0.606
Local intrawound vancomycin antibiotic powder	8.000	153.000	0.982
Dural tear	4.000	35.000	0.221
Postoperative prophylactic antibiotics, days	4.213	4.250	< 0.01
Perioperative with other infections, n (%)	1.000	19.000	1.000
BMI, body mass index; MT, muscle thickness; FT, fat thickness; DM, diabetes mellitus; SSI, surgical site infection; ASA, American Society of Anesthesiologists; VAS, Visual Analogue Scale; JOA, Japanese Orthopaedic Association.			

Table 2

Risk Factors for SSI in Posterior Cervical Spine Surgery Using Univariate and Multiple Logistic Regression Analysis

Variable	Univariate Logistic Regression Analysis		Multiple Logistic Regression Analysis		
	OR	P	OR	P	C.I.
Preoperative serum albumin (g/dL)	0.795	< 0.01	0.83	< 0.01	0.745–0.925
FT	1.392	< 0.01	1.022	0.844	0.82–1.275
Ratio of FT/MT	1.161	< 0.01	1.214	0.003	1.067–1.382
Preoperative JOA score	0.610	< 0.01	0.591	0.009	0.398–0.877
Postoperative drainage, mL	1.003	< 0.01	0.997	0.171	0.993–1.001
Time of draining, hours	1.044	< 0.01	8.347	0.011	1.020–1.170
FT, fat thickness; JOA, Japanese Orthopaedic Association.					

Table 3  
Previous Studies of Risk Factors for SSI in Posterior cervical Spine Surgery

Year	Study	Journal	Risk Factors
2012	Barnes [10]	Global Spine J	traumatic etiology, postoperative use of a collar
2013	Mehta [21]	J Bone Joint Surg Am	ratio of the FT to the lamina-to-skin distance
2016	Ojo [18]	Niger J Clin Pract	diabetes mellitus, obesity, and anemia
2016	Sebastian [33]	Spine J	BMI > 35, chronic steroid use, operative time > 197 minutes
2017	Cancienne [19]	Spine	preoperative cervical epidural steroid injections
2018	Herrick [24]	J Neurosurg Spine	no drain placement
2019	Cheng [22]	Spine J	BMI > 35, diabetes mellitus
2020	Fatima [23]	World Neurosurg	obesity
2020	Sridharan [11]	World Neurosurg	BMI ≥ 35.0

## Discussion

SSI has been found to be the most common complication in spinal surgeries serious consequences like debridement negative impact on patient-reported clinical outcomes, potential need for instrumentation removal, and increasing patient mortality. Therefore, SSI causes huge healthcare and economic burden. Previous studies have shown that the SSI rate following posterior cervical spine surgery range from 1.4%-13% higher than anterior cervical spine<sup>5,6,19</sup>. In our study, patients who had surgery for osteomyelitis, discitis, epidural abscess, primary or metastatic tumors were excluded due to their inherent risk of SSI. the overall rate of clinically significant SSI after posterior cervical spine surgery was 4.93%. the incidence of SSI reported in our study was consistent with that reported previously in the literature.

In previous reports on SSI, many estimated risk factors were reported. However, there are many debates regarding the risk factors of SSI. In this study, we performed univariate and multivariate analyses to investigate the impact of related risk factors for development of SSI. In the univariate analysis, subcutaneous FT (P < 0.001), ratio of subcutaneous FT/MT (P < 0.001), preoperative JOA Scores (P < 0.01), preoperative serum albumin (P < 0.01), postoperative drainage (P < 0.01), time of draining (P < 0.001) were identified as significant risk factors. in the multivariate logistic regression model, we entered all variables, except for those identified in the univariate analysis as no significant (P > 0.05) effects. With subsequent multivariate analysis, we were able to identify 4 independent factors ratio of subcutaneous

FT/MT ( $P < 0.01$ ), preoperative JOA scores ( $P < 0.01$ ), preoperative serum albumin ( $P < 0.001$ ), time of draining ( $P < 0.001$ ) influenced patients' risks of SSI following posterior cervical spine surgeries.

High BMI was a recognized, independent risk factor in SSI following spine surgery<sup>11,20</sup>. Currently, more and more studies have found that the distribution of subcutaneous fat at the site of surgery not high BMI has been previously shown to affect the risk of SSI following lumbar spine fusion, with the subcutaneous FT being an independent risk factor for infection<sup>21-23</sup>. This association has also been previously shown to increase the risk of SSI after spine surgery procedures. Obese patients are at a greater risk of SSI because of the increased the subcutaneous FT at the surgical site. The increased FT may require a longer incision, wider dissection, and increased retraction. Operative time is also increased because of the increased difficulty of the surgery in these patients. As retraction is prolonged, the duration of decreased blood flow becomes longer, increasing tissue necrosis at the surgical site. Besides, redundant soft tissues and a poor wound healing environment making closure of the wound challenging, which were possible reasons for an increased risk of SSI resulting from tissue necrosis in obese patients. In the present study, the MT was not a risk factor for SSI, demonstrating that FT is at the highest risk for necrosis while MT not. Thick subcutaneous FT may allow for the development of a dead space after wound closure. This can play a role in the development of SSI following posterior cervical spine surgery. In this study, we demonstrated that the most useful predictor of incisional SSI is the ratio of FT/MT, which reflects the distribution of subcutaneous fat more accurately excluding individually influence.

At present, the relationship between SSI following posterior cervical spine surgeries and surgical site drains is still controversial. The surgical site drain was mainly started in cervical spine surgeries to prevent the formation of epidural hematoma or seroma which may cause neurological deficit and increasing the tension on the incisions resulting in wound-related complications namely SSI and wound dehiscence<sup>24</sup>. Wound drain apart from supposedly aiding in SSI prevention, could cause retrograde infection, increase post-operative blood loss which increases the need for blood transfusion. In our study, drainage time was an independent risk factor for postoperative SSI. In addition, Payhs et al.<sup>25</sup> suggested that surgical site drains in the posterior cervical spine in combination with alcohol foam or vancomycin powder are associated with reduced odds of SSI among patients undergoing any posterior cervical spine surgery.

Current evidence demonstrates a strong and independent association between malnutrition and infectious and wound complications following posterior cervical spine surgeries<sup>15,16</sup>. Our results support the use of laboratory nutritional screening as a component of preoperative patient assessment and optimization to solve the difficulty of assessment of nutritional status of different people. In this study, decreased preoperative serum albumin ( $< 3.5$  g/dL) significantly increased the risk of postoperative SSI. Additionally, low albumin level would suppress the patients' immune function and impaired the wound healing, which increased the risk of SSI. Cooper et al.<sup>26</sup> reported nutritional supplementation may provide a small reduction in infections in the spine trauma population. At present, the relationship between SSI

following posterior cervical spine surgeries and preoperative malnutrition is still controversial, which needs to be confirmed by multicenter and large sample randomized controlled study.

At present, there are no study on the role of preoperative JOA score in SSI. In this study, we demonstrated an interesting result that preoperative JOA score was an independent risk factor of SSI following posterior cervical spine surgery. No clinical research pointed out this view before. A poor preoperative JOA score usually suggested to denervation, pressure sores and urinary retention. In one basic research, chronically denervated tissue is more susceptible to bacterial growth and difficulty in wound healing<sup>27,28</sup>. Poor nerve function may associate with difficulty getting out of bed resulting in pressure sores, and urinary retention may result in urinary tract infection. Those several reasons may attribute to SSI following posterior cervical spine surgery.

This study didn't support for vancomycin predicting SSI possibly due to small infection rates while previous studies supported<sup>4,29-31</sup>. A possible theory for our results that are in contrast to those of other vancomycin studies is that local vancomycin may not have enough capacity to overcome the increased infection risk factors seen in patients undergoing fusion. Thus, the addition of other treatment modalities may be needed to prevent SSIs in the high-risk fusion population, such as improved nutrition or more stringent patient selection criteria. An additional consideration is that the current dosing of intrawound vancomycin may not be adequate, or the delivery of the medication does not last long enough in the local environment to completely control bacterial growth for these large, deep incisions.

In prior studies, DM was identified as a significant risk factor for SSI after spinal surgery<sup>32</sup>. However, in our study, DM was not significantly associated with SSI. Blood glucose were well controlled before operation, the smaller number of patients with DM, and the inclusion of several potential risk factors in the final multivariate logistic model may have been responsible for these results. Due to the same types of surgery, the intraoperative segments are mostly 3 or 4, so the operation time is relatively close. Similarly, gender, steroid use, current smoking, history of previous SSI, estimated blood loss, and surgical procedure were not identified as risk factors in our study, although they have been found to be significant risk factors for SSI in previous studies<sup>33</sup>.

First, this was a retrospective nonrandomized case-control study, and the number of patients with SSI in this study was relatively small.

Our study has several limitations. First, this was a retrospective nonrandomized case-control study, and the number of patients with SSI in this study was relatively small. The low rate of SSI could have prevented us from detecting correlations and statistical differences on some variables. Multicentric data pooling could help increase the included number of patients and overcome this limitation. Second, some variables that have potential to influence the development of SSI were not included because they were not considered before the start of the study, such as type of cervical pathology, anticoagulation used, neurological outcomes, cause of death and adverse reaction to transfusion. In addition, in some cases, such as those vancomycin-related reactions, and liver disease, the sample size was too small to allow investigation of their effects on SSI occurrence. Owing to these limitations, high-quality observational

studies and basic experimental studies are still needed to investigate new risk factors for SSI further in the future.

## Conclusions

A total of 20 SSIs (4.93%) occurred in 405 cases of posterior cervical spine surgeries. Incidence of SSI significantly prolonged hospitalization, increased hospitalization expenses. Ratio of subcutaneous FT to MT, preoperative JOA score, preoperative serum albumin and longer time of draining were found to be significantly associated with SSI after posterior cervical spine surgeries. Identification of these risk factors for SSI could be of great value in risk-benefit analysis of prophylaxis after posterior cervical spine surgeries, and adequate management of preoperative risk to reduce SSI incidence. In addition, the results could be used in counseling patients and their families during the consent process.

## Abbreviations

SSI: Surgical site infection; BMI: Body mass index; JOA :Japanese Orthopaedic Association; DM: Diabetes mellitus; MT: Muscle thickness; FT: Fat thickness; ASA: American society of anesthesiologists; VAS: Visual analogue scale

## Declarations

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### Authors' contributions

CYA contributed to the study design, the writing of the paper, and drafting of the manuscript. LZH performed the surgeries and participated in the design of the study. YM, ZWT and XG collected and analyzed the data. LZH reviewed and edited the manuscript. All authors read and approved the final manuscript.

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### Availability of data and materials

All data used and analyzed during this study are available from the corresponding author upon reasonable request.

## Ethics approval and consent to participate

This research was approved by the ethics committee of the First Affiliated Hospital of Dalian Medical University. And agreement to participate was given by the participants. Because of the retrospective nature of the study, informed consent was waived.

## Consent for publication

Written informed consent for publication of their clinical details and/or clinical images was obtained from the patient/parent/guardian/relative of the patient.

## Competing interests

The authors declare that they have no competing interests.

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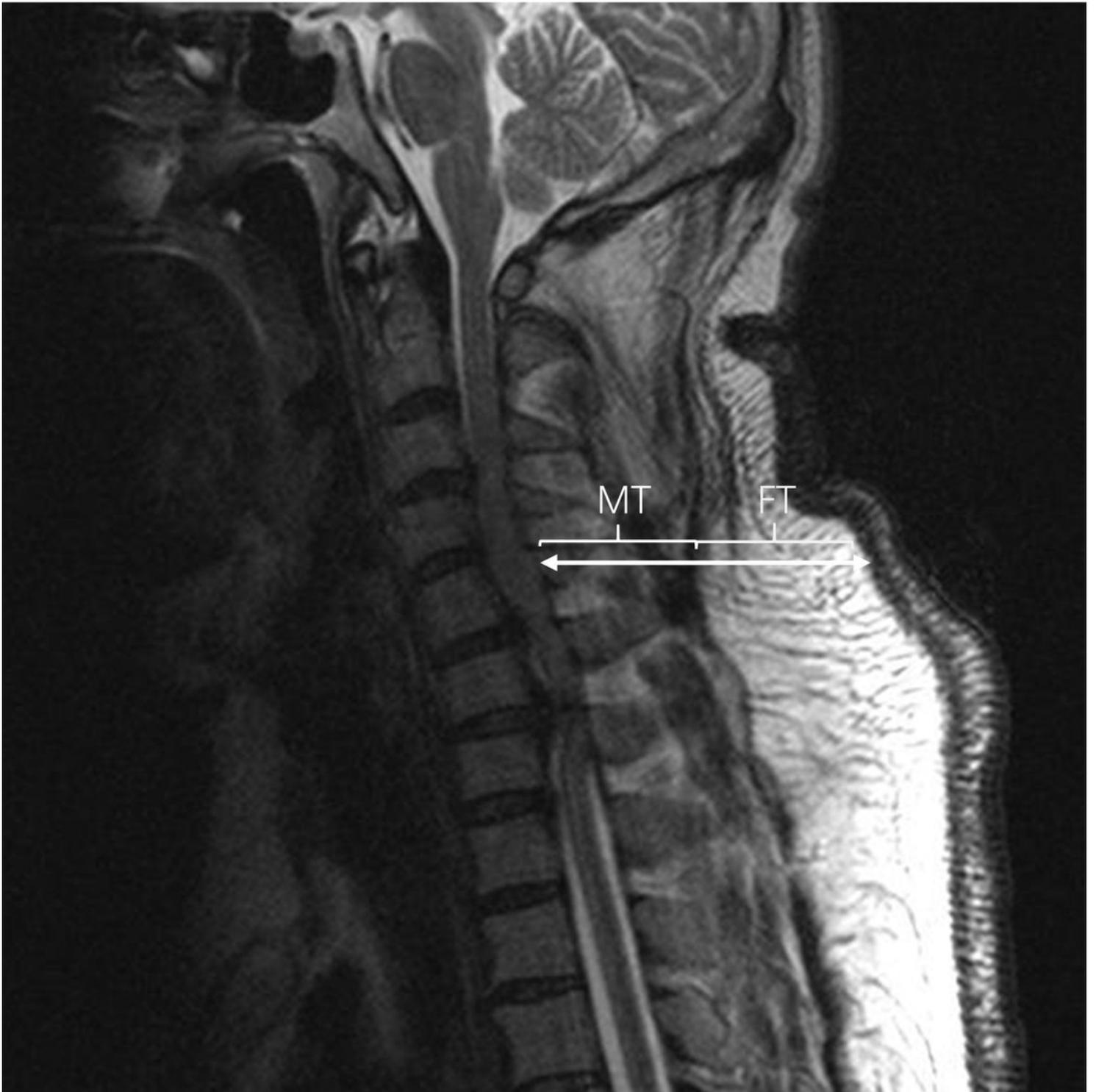
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## Figures



**Figure 1**

Method used to measure the MT, subcutaneous FT, and lamina at skin surface at the C5 level using sagittal views as determined on T2-weighted magnetic resonance imaging.