Journal of Surgery
2026, Vol. 14, No. 4, pp. 81–88
https://doi.org/10.11648/j.js.20261404.13

Research Article

Incidence and Risk Factors of Acute Kidney Injury After Spinal Tuberculosis Surgery: A Case-control Study with Propensity Score Analysis

Ruixue Li*

Department of Anesthesiology, West China Hospital, Sichuan University, Chengdu, China

Abstract

The aim of this study was to determine the incidence and risk factors of postoperative acute kidney injury (AKI) in patients with spinal tuberculosis surgery. And in this retrospective case-control study, patients were diagnosed with AKI after surgery according to kidney disease: improving global outcomes (KDIGO) guidelines. Multivariate logistic regression model was used to calculate the association between perioperative factors and AKI. A propensity score matching (PSM) evaluation was developed for adjustment and matching. The final result was that a total of 86 patients diagnosed AKI and 957 without AKI were selected from 1043 patients. After PSM analysis, preoperative anemia (OR, 3.57; 95%CI, 1.45-8.79; *P*=0.006), higher erythrocyte sedi-mentation rate (ESR) level (OR, 1.01; 95%CI, 1.00-1.03; *P*=0.029), intraoperative hypotension (OR, 3.42; 95%CI, 1.40-8.33; *P*=0.007) were predictors for postoperative AKI, and intraoperative dexmedetomidine (DEX) used (OR, 0.36; 95%CI, 0.14-0.91; *P*=0.030) was associated with a reduced risk for AKI. Patients with postoperative AKI were associated with increased rates of demanded for intensive care unit (ICU), and prolonged hospital length of stay (P<0.05). The final conclusion was that the postoperative AKI incidence was 8.25%. Moreover, Preoperative anemia, higher level of ESR and intraoperative hypotension can significantly increase the risk of AKI after spinal tuberculosis surgery. DEX infusion was associated with lower incidence of postoperative AKI.

Keywords

Acute Kidney Injury, Surgery, Spinal Tuberculosis, Case-control Study, Propensity Score

1. Introduction

Tuberculosis is one of the top ten causes of deaths. In 2018, there were about 10.0 million new cases of tuberculosis, and extrapulmonary tuberculosis accounted for 15% of the 7.0 million incident cases [1]. Osteoarticular tuberculosis is the most common extrapulmonary tuberculosis, which 50%~60% of them is spinal tuberculosis that vertebral tuberculosis is most common [2]. Spinal tuberculosis can be treated with anti-tuberculosis drugs. But insufficient blood supply, slow work, the dysfunction of spinal cord, neurological function and instability of spine attacked by the tuberculosis, all of those can cause that simply using anti-tuberculosis drugs is not effective. Surgical strategy can quickly debride tuberculosis infection lesions, which is of great significance in relieving the symp-

*Correspondence: Ruixue Li (2027581940@qq.com)

Received: 3 August 2026; **Accepted:** 9 August 2026; **Published:** 22 August 2026

toms of nerve compression, correcting kyphosis and rebuilding the stability of the spine [3, 4]. In spinal tuberculosis, clinicians always combined anti-tuberculosis drugs with surgery to treat patients who had clinical symptoms. However, spinal surgery can cause a lot of postoperative complications.

Postoperative acute kidney injury (AKI) is a critical clinical symptom caused by renal function rapidly declining, and it is one of the serious complications after surgery [5]. In previous studies, the incidence of AKI after major surgery was 11.8%, but different types of surgery with different incidence of AKI. Cardiac surgery had the highest incidence which was about 18.7% and orthopedic surgery was about 10.2% [6]. Previous studies argue that transient, reversible postoperative AKI is a benign condition, which does not carry a significant independent association with increased mortality [7]. However, Li S et al [8] reported that short-term, reversible AKI also increased the risk of long-term chronic kidney disease (CKD) and end-stage renal disease (ESRD). Ponte B et al [9] found that the incidence of further renal damage is up to 61.1% after 10 years in those patients. In fact, postoperative AKI has numerous clinical implications which are associated with postoperative infection, poor renal function and duration of hospital stay and healthcare cost [10].

In previous study, age, hypertension, and microalbuminuria were found to be the risk factors for postoperative AKI in major surgery [6, 8, 11]. However, little is known about postoperative AKI after spinal tuberculosis surgery. In this study, we conducted a retrospective analysis to identify the perioperative risk factors for AKI who underwent spinal tuberculosis surgery and clarify the relationship between postoperative AKI and the outcomes of patients.

2. Methods

2.1. Patients and Data Collection

This was a single-center, retrospective case-control study. The hospital prospectively established an electronic database of inpatients from October 2013 onward to improve patient management and clinical research. We included patients who were 18 years or older and underwent spinal tuberculosis surgery between January 2014 to June 2020. Patients who had been undergoing renal replacement therapy before surgery, had severe infection or sepsis, with mechanical renal injury occurred during surgery, been dead in 7 days after surgery, with incomplete and missing medical records regard to general clinical data or anesthesia records were excluded from the analysis. During the study period, patients who repeat spinal surgery in the same patients would record the first time into the analysis.

Demographic data collected including age, sex, American society of anesthesiologists (ASA) classification, body mass index (BMI), medical history like history of hypertension, CKD, Diabetes mellitus and so on. Preoperative laboratory data including serum creatinine, blood urea nitrogen (BUN), anemia, hypoalbuminemia, erythrocyte sedimentation rate (ESR). Intraoperative period factors recorded including hypertension, hypotension, medication using, fluid balance (crystalloid, urine output), blood loss, duration of surgery and so on. Postoperative data included the hospital stay, ICU stay, and overall mortality.

2.2. Anesthetic Management

All patients underwent balanced anesthesia (sevoflurane and propofol). Positive inotropic drugs and vasoactive drugs were selected based on the anesthesiologist's evaluation. Intraoperative blood loss is mainly supplemented by crystals. Erythrocyte transfusions were guided by standard clinical practice guidelines that intraoperative blood gas analysis show the hemoglobin was <80 g/L [12]. Postoperative analgesia was intravenous patient-controlled analgesia.

2.3. Definitions

The diagnosis AKI in our study using serum creatine change according to the kidney disease: improving global outcomes (KDIGO) guidelines [13]. According to the World Health Organization, preoperative anemia defined as: hemoglobin <130 g/L for men and <120 g/L for women. Intraoperative hypertension was defined blood pressure increased more than 20% of the baseline value or is over 140/90 mmHg during operation. Intraoperative hypotension was defined blood pressure reduced more than 20% of the baseline value or the systolic blood pressure is lower than 80 mmHg.

2.4. Statistical Analysis

Continuous variables were expressed as medians with range or mean ± SD. Normally and non-normally distributed continuous data were analyzed using independent t test or Wilcoxon rank sum test, respectively. Categorical data were analyzed using $\chi 2$ or Fisher exact testing, where appropriate. In this study, we used a propensity score matching (PSM) analysis to further control the effects of confounding factors. A multivariate logistic regression model was used to calculate the propensity score for AKI group and non-AKI group. The model used patients' demographics and preoperative medical status as covariates. propensity scores data is between 0~1. The two groups were sorted according to the size of the propensity scores. Then selecting a case from the AKI group, next picking up the most similar case in the non-AKI group as the matching individual according to the propensity scores. In PSM analysis, we employed a one-to-one greedy nearest neighbor matching method without replacement to select patients, with a caliper of 0.2. Univariate logistic regression model was used to explore the potential risk factors for postoperative AKI and to provide a reference for subsequent data analysis. Multivariate logistic regression model was used to identify the risk factors for postoperative AKI and calculated

adjust odds ratios (OR) and 95% confidence intervals (95%CI). Covariate included in multivariate logistic regression models were determined on the basis of the clinical relevance and potential risk factors associated with univariate logistic regression analysis ($P < 0.1$). We used SPSS software, version 24.0 (IBM SPSS statistics, Chicago, IL, USA) to conduct all data analyses. Statistical significance level was set at $P<0.05$ under a two-tailed test.

3. Result

A flow diagram showing the selection of patients is presented in (Figure 1). We evaluated 1321 patients who underwent spinal tuberculosis surgery. After excluding 143 patients who repeat undergoing surgery, 56 patients were missing data, 78 patients younger than 18 years old, and 1 patient died on 7 days after surgery. A total of 1043 patients were included in the final analysis.

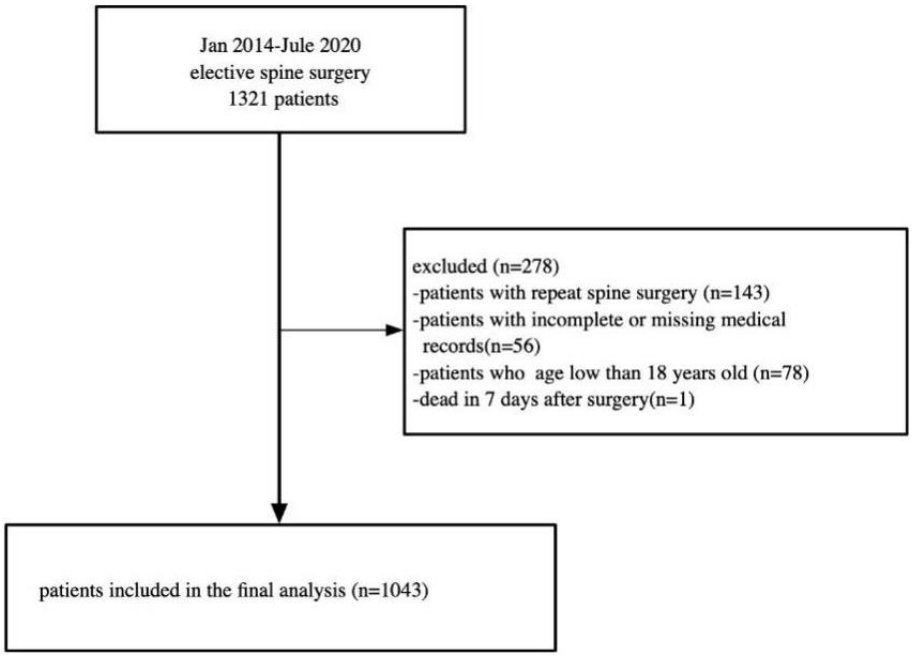

Figure 1. *Flow chart with inclusion and exclusion criteria used in the analysis.*

Overall, postoperative AKI occurred in 86/1043 patients (8.25%) during the hospitalization period which stage 1 in 82/86 (95.35%) patients, stage 2 in 3/86 (3.49%) patients, and stage 3 in 1/86 (1.16%) patient on day 1 after surgery. Stage 1 in 9 patients, stage 2 in 1 patient, and stage 3 in 1 patient on day 7 after surgery. one patient was still in stage 1 when left hospital (Figure 2).

Figure 2. *Number of patients who diagnosed with postoperative acute kidney injury (AKI) based on global disease improvement global outcomes (KDIGO).*

Baseline characteristics of AKI and non-AKI patients in the entire samples and matched sample are shown in (Table 1). After PSM, a total of 82 matched pairs of cases and controls

were obtained. All selected covariates were well balanced between AKI and non-AKI (all p>0.05). Multivariable regression assessment revealed that preoperative higher ESR level was a risk factor for AKI before (OR, 1.01; 95%CI, 1.00-1.02; p<0.001) and after PSM (OR, 1.01 95%CI, 1.00-1.03; p=0.029). Preoperative anemia was a risk factor for AKI before (OR, 5.03; 95%CI, 2.76-9.16; p<0.001) and after PSM (OR, 3.57; 95%CI, 1.45~8.79; p=0.006). Intraoperative hypotension were also associated with AKI before (OR, 3.71; 95%CI, 2.09~6.56; p<0.001) and after PSM (OR; 3.42; 95%CI, 1.40~8.33; p=0.007). Intraoperative dexmedetomidine reduced the risk of postoperative AKI before (OR, 0.44; 95%CI, 0.25~0.79; p=0.006) and after PSM (OR, 0.36; 95%CI, 0.14~0.91; p=0.030) (Tables 1 and 2).

Table 1. *Demographic, clinical and laboratory characteristics of patients before and after propensity score matching.*

Variables	Entire samples			Matched samples		
	Patients with AKI (n=86)	**Patients without AKI (n=957)**	***p* value**	**Patients with AKI (n=82)**	**Patients without AKI (n=82)**	***p* value**
Patients' demographics						
Age (yr)	51 (59.3)	282 (29.4)	<0.001	48 (58.5)	50 (60.9)	0.750
Sex, male	51 (59.3)	495 (51.7)	0.178	35 (42.6)	29 (35.3)	0.337
BMI (kg/m^2)	23.1 (21.0~25.6)	22.1 (19.5~24.7)	0.457	23.5 ±3.4	23.41 ±3.6	0.337
ASA III~IV	41 (47.6)	263 (27.4)	<0.001	38 (46.3)	38 (46.3)	1.000
Hypertension	40 (46.5)	161 (16.8)	<0.001	38 (46.3)	37 (45.1)	0.875
Diabetes mellitus	15 (17.4)	90 (9.4)	0.018	13 (15.8)	15 (18.2)	0.678
CKD	6 (6.9)	4 (0.4)	<0.001	2 (2.4)	0 (0)	—
Cerebrovascular disease	6 (8.1)	21 (2.1)	0.020	6 (7.3)	5 (6.1)	0.755
Coronary arterial disease	15 (17.4)	45 (4.7)	<0.001	13 (15.8)	14 (17.0)	0.833
Hypoalbuminemia	49 (56.9)	275 (28.7)	<0.001	45 (54.8)	29 (35.3)	0.013
Anemia	42 (48.8)	197 (20.5)	<0.001	38 (46.3)	54 (65.8)	0.012
ESR (mm/h)	49.5 (18.7~76.0)	29.0 (14.0~55.0)	<0.001	50.0 (18.0~76.0)	30.0 (17.7~49.5)	0.005
BUN (mmol/L)	4.6 (3.6~5.9)	4.1 (3.3~5.2)	0.836	4.6 (3.6~5.7)	4.2 (3.3~4.8)	0.816
Serum creatinine (μmol/L)	63.4 (46.2~80.9)	58.9 (50.7~69.1)	<0.001	62.0 (46.0~77.1)	61.5 (52.8~70.0)	0.363
Proteinuria	37 (43.0)	260 (27.2)	0.002	36 (43.9)	21 (25.6)	0.015
Intraoperative variables						
Hypertension	38 (44.1)	233 (24.3)	<0.001	36 (43.9)	30 (36.5)	0.340
Hypotension	42 (48.8)	182 (19.0)	<0.001	39 (47.5)	20 (24.3)	0.002
Dexmedetomidine	42 (48.8)	639 (66.7)	0.001	40 (48.7)	51 (62.2)	0.085
Tranexamic acid	25 (29.0)	380 (39.7)	0.053	24 (29.2)	34 (41.4)	0.104
NSAIDs	26 (30.2)	336 (35.1)	0.363	26 (31.7)	22 (26.8)	0.493
Blood loss (ml)	500 (400~800)	500 (300~700)	0.007	500 (300~800)	500 (300~700)	0.187
Erythrocyte transfusion (ml)	0 (0~200)	0 (0~400)	0.001	400 (0~400)	0 (0~400)	0.136
Crystalloids (ml)	2800 (2100~3400)	2700 (2350~3300)	0.583	2750 (2100~3325)	2700 (2175~3250)	0.485
Urinary output (ml)	210 (200~400)	250 (200~400)	0.280	210 (200~362)	255 (200~412)	0.171
Duration of surgery (min)	168.0 (137.5~220.0)	184.5 (147.0~230.7)	0.085	168.0 (137.5~221.5)	181.5 (139.7~226.2)	0.615

BMI: body mass index, ASA: American society of anesthesiologist's physical classification, CKD: Chronic kidney disease, ESR: erythrocyte sedimentation rate, BUN: blood urea nitrogen, NSAIDs: Non-Steroidal Anti-inflammatory Drugs

Table 2. *Multivariable logistics regression analysis of factors that are related to postoperative AKI after spinal tuberculosis surgery before and after propensity score matching.*

	Entire samples		Matched samples	
	OR (95%CI)	***p* Value**	**OR (95%CI)**	***p* Value**
Preoperative hypertension	2.10 (1.14~3.88)	0.017		
Preoperative CKD	5.46 (1.06~27.98)	0.042		
Hypoalbuminemia	1.85 (1.02～3.35)	0.042	0.51 (0.21～1.21)	0.129
Serum creatine	1.01 (1.00~1.03)	0.028		
ESR	1.01 (1.00~1.02)	<0.001	1.01 (1.00~1.03)	0.029
Proteinuria	1.87 (1.08~3.23)	0.025	0.55 (0.25~1.23)	0.151
Anemia	5.03 (2.76～9.16)	<0.001	3.57 (1.45～8.79)	0.005
Intraoperative hypertension	1.85 (1.07~3.20)	0.027		
Intraoperative hypotension	3.71 (2.09~6.56)	<0.001	3.42 (1.40~8.33)	0.007
Dexmedetomidine	0.44 (0.25~0.79)	0.006	0.36 (0.14~0.91)	0.030
Tranexamic acid	0.38 (0.21~0.69)	0.002		

OR: odds ratios, 95%CI: 95% confidence intervals, CKD: Chronic kidney disease, ESR: erythrocyte sedimentation rate

In AKI group, there was one patient need RRT in our research. ICU was need more in the AKI group compared to the non-AKI group before [26 (30.2%) vs 51 (5.3%) p=0.0001] and after PSM [2 (26.8%) vs 8 (9.7%) p=0.0005]. Hospital stay was also considerably extended in the AKI group compared to the non-AKI group before [18.0 (15.0-27.6) vs. 14.0 (12.0-17.5) days; p = 0.013] and after PSM [15.0 (12.0~21.2) vs. 13.0 (11.0~18.0) days; p = 0.044] (Table 3).

Table 3. *Postoperative clinical outcomes by status of AKI before and after propensity score matching.*

Variables	**Entire samples**			**Matched samples**		
	Patients with AKI (n=86)	**Patients without AKI (n=957)**	**P-value**	**Patients with AKI (n=86)**	**Patients without AKI (n=957)**	**P-value**
ICU needed	26 (30.2)	51 (5.3)	0.0001	22 (26.8)	8 (9.7)	0.005
Hospital days	18.0 (15.0~27.6)	14.0 (12.0~17.5)	0.013	15.0 (12.0~21.2)	13.0 (11.0~18.0)	0.044
RRT	1 (1.1)	0		0	0	

ICU: Intensive Care Unit, RRT: Renal replacement therapy

4. Discussion

This is the first study to explore the incidence and risk factors of postoperative AKI in spinal tuberculosis surgery. We confirmed some of the risk factors for AKI that rarely been shown in other surgical populations, including preoperative ESR level, intraoperative dexmedetomidine.

There are few findings on the occurrence of AKI after surgical treatment of patients with spinal tuberculosis. Our research results have certain guide significance for the clinic. Our results differ from Tracey et al. [14] who showed that perioperative diuretics, non-steroidal anti-inflammatory drugs and angiotensin-converting enzyme inhibitor or angiotensin receptor blocker were significantly associated with the occurrence of postoperative AKI in major orthopedic surgery. They use Risk-Injury-Failure-Loss-End stage renal disease (RIFLE)

criteria to defined postoperative AKI. The result of Ka lender M et al [15] shown the KDIGO guidelines was superior to RIFLE criteria regard its prognostic power.

The associated between preoperative anemia and postoperative AKI has been described in patients with femoral neck fractures [16]. Patients with tuberculosis often have anemia which can result in poor treatment outcomes. Sahiratmadja et al [17] studies have found that 63.2% patients with tuberculosis have anemia which can not only increase the incidence of postoperative complications in tuberculosis surgery but also increased risk of death [18, 19]. The potential mechanism of AKI caused by anemia is complex and haven't be fully understood. But some study has identified several mechanisms that may explain why anemic patients seem to be more susceptible to have postoperative AKI. Kidneys are vulnerable to hypoxic injury in the setting of reduced oxygen delivery due to chronic anemia [20]. Even having normal creatinine values, anemic patients have subclinical kidney disease that is characterized by increased renal tubular oxygen consumption and oxidative stress [21]. All of those can make kidney easier to develop postoperative AKI than without anemia.

ESR is a frequently performed laboratory test that measures the rate at which erythrocytes suspended in plasma settle when placed in a vertical tube [22]. The elevated rate doesn't reveal a specific disease, but it is a marker of underlying disease. The main disease of elevated ESR is involving increased levels of plasma protein/fibrinogen like active tuberculosis or cardiovascular disease. Our results show that preoperative higher ESR level was an independent risk factor for postoperative AKI. Yuan et al. [23] found that ESR level caused by contrast agents were associated with AKI in patients who undergoing percutaneous coronary intervention, and it had a predictive value on contrast-induced AKI in patients who underwent an emergency percutaneous coronary intervention. Kangari et al. [24] found that ESR has stronger specificity than urine β2-microglobulin in predicting renal damage in children with acute pyelonephritis. When ESR level is higher, it indicates that the body is in high inflammatory response, which increased permeability of renal vascular endothelial cells that increase the risk of postoperative AKI in patients.

We also found that perioperative hypotension was associated with the development of AKI in spinal tuberculosis surgery. In a large retrospective analysis, Maheshwari K et al [25] found anesthetists should avoid mean arterial pressure < 65 mmHg to decrease postoperative AKI during surgery. On some major surgery like orthopedic surgery and pelvic surgery, it is generally recommended clinicians could control hypotension to decrease intraoperative blood losing, transfusion requirements, shorten operation time, improve the quality of the surgical field, and prevent deep vein thrombosis. However, it may lead hypotension and intraoperative dehydration that cause endothelial injury in turn and the subsequent local release of endothelin, angiotensin II, and catecholamines. All of that cause vasoconstriction and exacerbate ischemia in the kidney [26, 27]. The relationship between hypotension and AKI was clearly observed in our study. Therefore, clinicians should pay more attention to intraoperative hypotension and correct it as soon as possible to prevent the occurrence of postoperative AKI.

This is the first study found that postoperative dexmedetomidine infusion is associated with lower incidence of AKI in spinal tuberculosis patients. Even after adjustment for potential confounders after PSM analysis also observed the similar result. Our study found that dexmedetomidine has renoprotective properties. Ji F et al [28] found that coronary artery bypass grafting patients who use dexmedetomidine were less likely to develop AKI, especially among patients with baseline normal kidney function. The exact mechanism of dexmedetomidine for renal protection is not completely understood, but it is probably related to the combination of anti-inflammatory, cytoprotective and sympathetic effects. In a sepsis model, Hosing CH et al [29] found that rats treated with dexmedetomidine had a lower AKI incidence, decreased level of tumor necrosis factor-α, increased expression of the anti-inflammatory protein bone morphogenetic protein-7. Gu J et al [30] found that in ischemia-reperfusion mouse model, dexmedetomidine may has additional cytoprotective effects through the α2-adrenoceptor activation of cell survival signal phospho-serine/threonine protein kinase (p-AKT), and reduced sympathetic effect drive by modulate vasoreactivity, potentially improve renal blood fowl through the down-regulation of the vasoconstrictor endothelin-1 [31]. Thus, dexmedetomidine has many actions that may prevent AKI.

As with all retrospective studies, the study is dependent on accuracy and availability of data. Further, the potential for confounding and unmeasured variables always exists. For instance, we did not have information about duration of hypotension, dose of dexmedetomidine administered during surgery. We only have data on presence or absence of comorbidities but not severity. Secondly, we didn't have long-term renal function follow-up data. Because most of patients don't have multiple serum creatinine laboratory examination before surgery, we selected the serum creatinine data that closest to the operation as the baseline. Therefore, the actual occurrence of AKI might have been underestimated in our patient population.

5. Conclusion

In conclusion, AKI is a common complication after spinal tuberculosis surgery. Postoperative AKI can significantly increase the need to stay in ICU, and prolonged hospitalization. Preoperative anemia, preoperative higher level of ESR and intraoperative hypotension can significantly increase the risk of AKI after spinal tuberculosis surgery. dexmedetomidine appears to have a protective effect. However, those findings should be interpreted with caution. A randomized controlled trial should be conducted to test the efficacy of dexmedetomidine in reducing the occurrence of AKI after spinal tuberculosis surgery.

Abbreviations

AKI	Acute Kidney Injury
KDIGO	Kidney Disease: Improving Global Outcomes
PSM	Propensity Score Matching
ESR	Erythrocyte Sedi-mentation Rate
DEX	Dexmedetomidine
ICU	Intensive Care Unit
CKD	Chronic Kidney Disease
ESRD	End-stage Renal Disease
ASA	American Society of Anesthesiologists
BMI	Body Mass Index
BUN	Blood Urea Nitrogen
OR	Odds Ratios
95%CI	95% Confidence Intervals
BMI	Body Mass Index
NSAIDs	Non-Steroidal Anti-inflammatory Drugs
RRT	Renal replacement therapy
RIFLE	Risk-Injury-Failure-Loss-End
p-AKT	Phospho-serine/Threonine Protein Kinase

Author Contributions

Ruixue Li: Data curation, Methodology, Formal analysis, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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