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Original Article

Femoral Neck System vs. four cannulated screws in the treatment of Pauwels III femoral neck fracture

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A B S T R A C T

Objective: To compare the clinical efficacy of the Femoral Neck System (FNS) vs. four cannulated screws in Pauwels III femoral neck fractures.
Methods: This retrospective study included patients with newly occurred type Pauwels III femoral neck fracture treated at author' Hospital of between January 2017 and February 2021. The patients received FNS (n = 27) or four cannulated screws (control group, n = 31). The operation time, blood loss, fracture healing time, incidence of complications (such as short femoral neck, necrosis of femoral head, nonunion of fracture, and failure of internal fixation withdrawal), and hip Harris score at the last follow-up were analyzed.
Results: The operation time, blood loss, and fracture healing time were not significantly different between the two groups (all $P > 0.05$). In the FNS group, three and one patients were with femoral neck shortening and femoral head necrosis, respectively, while no fracture nonunion or failure of internal fixation withdrawal occurred. In the control group, seven, two, one, and two patients were with femoral neck shortening, femoral head necrosis, nonunion, and internal fixation failure, respectively. The cumulative complication incidence was 14.8% and 38.7% in the FNS and control groups ($P = 0.042$). The excellent and good rates of the hip Harris score at the last follow-up were 92.6% and 71.0% in the FNS and control groups, respectively ($P = 0.036$).
Conclusion: The study suggested that the clinical efficacy of FNS was better than internal fixation using four cannulated screws in treating Pauwels III type femoral neck fracture.

1. Introduction

Hip fractures involve a fracture of the upper portion of the femur (anywhere from the femoral head to about 5 cm below the lesser trochanter), typically resulting in groin and thigh pain. If the fracture is displaced, the affected extremity generally appears shortened with the hip positioned in external rotation and abduction, and the patient cannot bear weight [1,2]. About 90% of hip fractures involve falls [3]. Osteoporosis is the main risk factor that increases hip fracture risk, particularly in women [3]. Femoral neck fracture accounts for about 55% of all hip fractures in older adults, and most patients are females [4]. With the aging of the population, the incidence and prevalence of femoral neck fracture in older adults are increasing substantially [4].

Due to the femoral neck's unique blood supply and biochemical features, femoral neck fractures involve a high incidence of complications accompanying the bone fracture [5,6]. In Pauwels III fractures, the Pauwels angle is >50° [7]. In such fractures, the inversion stress and vertical shear force are higher than in the other types, increasing the risk of internal fixation failure, nonunion, and ischemic necrosis [8–10]. Pauwels III fractures usually occur in young patients and result from high-energy trauma [11,12].

Traditionally, the implantation materials for treating femoral neck fracture mainly include three cannulated screws or a sliding hip screw (DHS) with an anti-rotation screw [9]. When using three cannulated screws in an inverted triangle to treat Pauwels III femoral neck fracture, the postoperative risk of treatment failure and incidence of complications are relatively high due to the sub-optimal anti-inversion stress and vertical shear force [13,14]. DHS plus an anti-rotation screw has advantages in the treatment of basicervical femoral neck fractures and high angle Pauwels fracture but also has several disadvantages such as large incision, tissue

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dissection, high blood loss volume, and high torque of the implanted sliding screw leading to reduction loss at the fracture end (poor rotation) [15].

In order to improve the stability of internal fixation and therefore achieve better anti-vertical shear force, several researchers modified the surgery from the aspects of the construction and numbers of the cannulated screws. In studies performed by Gumustas et al. [16] and Li et al. [13], the biomechanical measurements and clinical efficacy analysis showed that the use of four cannulated screws (three screws in an inverted triangle plus one transverse screw) had higher biomechanical stability, could better anti-shear force, and achieved higher treatment efficacy.

Recent studies reported that fixation using the Femoral Neck System (FNS; DePuy Synthes) for unstable femoral neck fracture could achieve higher biochemical stability than using three cannulated screws [15,17]. In addition, the FNS has the advantages of minimally invasive implantation, being easy to operate, and angle and anti-rotation stability [15,17]. Still, no previous studies compared the treatment efficacy of four cannulated screws vs. FNS fixation in treating Pauwels III femoral neck fracture. In addition, no consensus on the best materials for internal fixation in patients with Pauwels III fracture has been reached yet [5].

Therefore, this study retrospectively analyzed the clinical data of 58 patients with Pauwels III femoral neck fracture treated with either FNS fixation or fixation using four cannulated screws (inverted triangle plus transverse) between January 2017 and February 2021 and compared the clinical benefits of the two methods.

2. Methods

2.1. Study design and patients

This retrospective study included patients with newly occurred type Pauwels III femoral neck fracture treated at the author' institution between January 2017 and February 2021. This study was approved by the IRB of the authors' affiliated institutions. The requirement for individual consent was waived by the committee.

The inclusion criteria were (1) 18–65 years of age, (2) with newly occurred type Pauwels III femoral neck fracture (i.e., fracture occurred within 3 weeks, with a Pauwels angle $\geq 50°$), and (3) the fracture included transcervical femoral fracture and fracture of femoral head and neck, according to the site of fracture. The exclusion criteria were (1) with pathological fracture, (2) accompanied with multiple fractures of the ipsilateral hip or adjacent sites, (3) accompanied with severe multiple injuries to other organs, (4) with underlying femoral head ischemia necrosis or hip osteoarthritis, or (5) with coagulation disorders.

The patients were grouped as FNS fixation (FNS group) and the four cannulated screws (in an inverted triangle + transverse distribution) fixation group (control group), according to the fixation methods.

2.2. Surgical methods

The patients were placed supine on the multifunction traction table for orthopedic surgery after general anesthesia or continuous epidural anesthesia, and traction reduction was performed. For patients with traction reduction failure, the 3-dimensional head-neck interaction technique was adopted under imaging guidance to achieve a satisfactory reduction as possible. The reduction failed in one patient in each group, who received open reduction through the Smith-Petersen approach. For the patients in the FNS group, after the reduction was satisfactory, routine disinfection and draping were performed. Percutaneous insertion of the first guidewire at the superior femoral neck level was performed to prevent secondary dislocation of the femoral neck. A longitudinal incision of 3.5–4.0 cm was made at the level of the lesser trochanter at the lateral thigh, and parosteal blunt dissection was also performed. The second guidewire was implanted along with the guide apparatus under imaging guidance. The direction and location of the guidewire were adjusted, the depth was measured, and the channel was expanded along the guidewire. Then, the primary nail of the FNS, which was equipped with a guider, was implanted to the corresponding depth. The distal locking screw and the anti-rotation screw were planted successively. A pressure device was used for the pressure on the fracture end.

For the patients in the control group, three cannulated screws were routinely implanted in an inverted triangle distribution and were closely superior to the femoral calcar, anteriosuperior of the femoral neck, and at the posterosuperior bone cortex, respectively. Then, the fourth cannulated screw was planted transversely, vertical to the direction of the fracture.

2.3. Data collection and outcomes

The baseline characteristics, intraoperative blood loss volume, operation time, fracture healing time, and incidence of complications such as short femoral neck, necrosis of femoral head, nonunion of fracture, and failure of internal fixation withdrawal were collected. The hip Harris score at 12 months after the operation was also collected. The hip Harris score ranges from 0 to 100, with 90–100 points indicating excellent outcomes, 80–90 points indicating good outcomes, 70–79 points indicating fair outcomes, and <70 points indicating poor outcomes [18].

The bone healing time was assessed according to the bony union criteria: (1) no pressure pain or longitudinal percussion pain; (2) no abnormal local motility; (3) X-ray imaging showed that the fracture line was blurred, with continuous callus through the fracture line; (4) the patient could walk continuously for 3 min and no less than 30 paces without support from canes or walking aids; (5) no deformity at the fracture site was observed after 2 weeks' continuous evaluation.

2.4. Statistical methods

SPSS 20.0 (IBM, Armonk, NY, USA) was used for statistical analysis. Continuous data were described as means and standard deviations and compared with the independent t-test. Categorical data were described as n (%) and compared with the chi-square test. $P < 0.05$ was considered statistically significant.

3. Results

Twenty-seven patients, including seven males and 20 females, were included in the FNS group. Their mean age was 57.9 ± 7.1 year (range, 33–65 years). The Garden types of the fracture included type II in five patients, type III in 15, and type IV in seven. The mean time from injury to operation was 2.6 days (range, 2–5 days); in the control group, this interval was 2.5 days (2–5 days) ($P = 0.819$). In the control group, 31 patients (including nine males and 22 females) were included. Their mean age was 57.6 ± 8.7 years (range, 23–65 years). The Garden types of fracture included type II in six patients, type III in 17 patients, and type IV in eight patients. The preoperative anteroposterior and lateral view Garden alignment index were <150° and >195°, respectively, in both groups, with poor alignment. The general characteristics of the patients, including age, sex, fracture type, preoperative Garden alignment index, and causes of fracture, were not significantly different between the two groups (all $P > 0.05$) (Table 1). The

Table 1
Characteristics of the patients.

Characteristics	FNS (n = 27)	Control (n = 31)	P
Age (years)	57.9 ± 7.1	57.6 ± 8.7	0.896
Sex (M/F)	7/20	9/22	0.792
Causes of injury			0.932
Car accident	4 (14.8)	5 (16.1)	
Fall from height	6 (22.2)	6 (19.4)	
Falling	17 (63.0)	16 (51.6)	
Garden type			0.997
II	5 (18.5)	6 (19.4)	
III	15 (55.6)	17 (54.8)	
IV	7 (25.9)	8 (25.8)	
Preoperative Garden alignment index			
Anteroposterior view	146.04 ± 3.94	145.81 ± 4.61	0.840
Lateral view	197.04 ± 5.30	195.84 ± 5.75	0.420
Operation time	51.7 ± 4.3	43.8 ± 4.1	0.175
Blood loss volume	50.3 ± 4.3	41.5 ± 5.7	0.081
Postoperative Garden alignment index			
Anteroposterior view	158.33 ± 1.47	158.23 ± 1.41	0.78
Lateral view	180.56 ± 0.58	180.77 ± 0.80	0.246

operation time was 51.7 ± 4.3 and 50.3 ± 4.3 min in the FNS and control groups, respectively (P = 0.175). The intraoperative blood loss volume was 43.8 ± 4.1 and 41.4 ± 5.7 mL in the FNS and control groups, respectively (P = 0.081) (Table 1). During operation, the fracture ends of patients in both groups were satisfactorily reduced (anteroposterior and lateral view Garden alignment index of 155°–180° and 180°, respectively). There was also no significant difference in the postoperative Garden alignment index between the two groups.

The Harris score was 87.6 ± 5.5 and 82.8 ± 8.1 in the FNS and control groups, respectively, and the difference was statistically significant (P = 0.010). The excellent/good hip joint function recovery rate was 92.6% and 70.9% in the FNS and control groups, respectively (P = 0.036) (Table 2).

Among the 27 patients in the FNS group, three and one patients were found with short femoral neck and necrosis of the femoral head, respectively, while no patients were found with nonunion of fracture or failure of internal fixation withdrawal. Among the 31 patients in the control group, seven, two, one, and two patients were with short femoral neck, necrosis of femoral head, nonunion of fracture, and failure of internal fixation withdrawal, respectively. The cumulative incidence of complication in the FNS group was significant lower than that in the control group (14.8% vs 38.7%, P = 0.042) (Table 3).

4. Discussion

Currently, the treatments for femoral neck fracture mainly include internal fixation and hip joint replacement. It is generally acknowledged that hip joint replacement is the preferred

Table 2
Fracture healing time and hip joint functions between the two groups.

Characteristics	FNS (n = 27)	Control (n = 31)	P
Fracture healing time (days)	177.2 ± 5.7	179.2 ± 4.8	0.144
Harris score	87.6 ± 5.5	82.8 ± 8.1	0.010
Excellent	18 (66.7)	14 (45.2)	
Good	7 (25.9)	8 (25.8)	
Fair	2 (7.4)	7 (22.6)	
Poor	0	2 (6.5)	
Excellent/good hip joint function recovery	25 (92.6)	22 (70.9)	0.036

Table 3
Complications.

Characteristics	FNS (n = 27)	Control (n = 31)	P
Short femoral neck	3 (11.1)	7 (22.6)	
Femoral head necrosis	1 (3.7)	2 (6.5)	
Nonunion	0	1 (3.20	
Internal fixation withdrawal failure	0	2 (6.5)	
Total	4 (14.8%)	12 (38.7%)	0.042

treatment for patients >80 years with severe osteoporosis, while for patients <65 years, anatomical reduction, rigid fixation, and preserving the hip joint are the major treatment targets, especially for patients with abundant daily activities. In addition to age, factors such as life expectancy, preoperative activity, systemic conditions, osteoporosis, and financial conditions should be considered when selecting the treatment method [19,20].

Closure reduction and internal fixation with multiple cannulated screws have several advantages, including easy to operate, minimally invasive, with good effects, and low expenses, and have become a commonly used method for the treatment of displaced femoral neck fractures [1,21]. In addition, screw placement is performed according to the principle of "closely adjacent, in parallel, inverted triangle, and screwhead in circular sector distribution", and the screw placement channel is optimized, which could increase the holding force of the screws to the cortical bone [22,23]. Nevertheless, studies suggested that using three cannulated screws was unsuitable for the fixation and treatment of Pauwels III femoral neck fracture, as the fixation could not support the vertical shear force at the fracture end [13,14]. It is generally acknowledged that anatomical reduction and stable and strong fracture fixation early after injury are important factors ensuring good treatment effects [24–26]. Two different fixation methods (FNS vs. four cannulated screws) were performed in the study period to treat Pauwels III femoral neck fracture. Previous studies have already demonstrated that these two fixation methods could provide higher biomechanical stability than using three cannulated screws [13,15–17]. In the present study, the treatment efficacy was higher in the FNS group, mainly manifested by advantages in preventing complications such as short femoral neck and failure of internal fixation withdrawal (Figs. 1 and 2) and better recovery of hip joint functions.

In this study, treatments by FNS and cannulated screws had similar characteristics, including minimal invasiveness, small incision, small blood loss, and ease of operation. The incision length was about 3 cm in the FNS group. One patient in the FNS and control groups underwent open reduction due to failure of closure fixation, while all the other patients underwent closed reduction. The reductions in all the patients were satisfactory. Still, three of the 27 patients in the FNS group were with evident femoral neck shortening (>10 mm), while no plate withdrawal was observed. When using cannulated screws for fixation, femoral neck fracture healing processes involve the resistance against fracture collapse. Such collapse could generally lead to the lateral withdrawal of the screws or even fixation failure and discomfort or pain in the thigh. The fractures in the patients were all well healed, but the femoral necks were slightly shortened, and four screws were with a slight withdrawal. The withdrawal of many screws could induce traction pain of the lateral thigh muscles, consequently influencing the hip functions and reducing the hip Harris score. Therefore, the healing of symptomatic fractures is generally associated with femoral neck collapse and shortening, adversely influencing the hip abductor functions and gait. In addition, the inversion and shortening of the femoral neck are also negatively correlated with the hip Harris

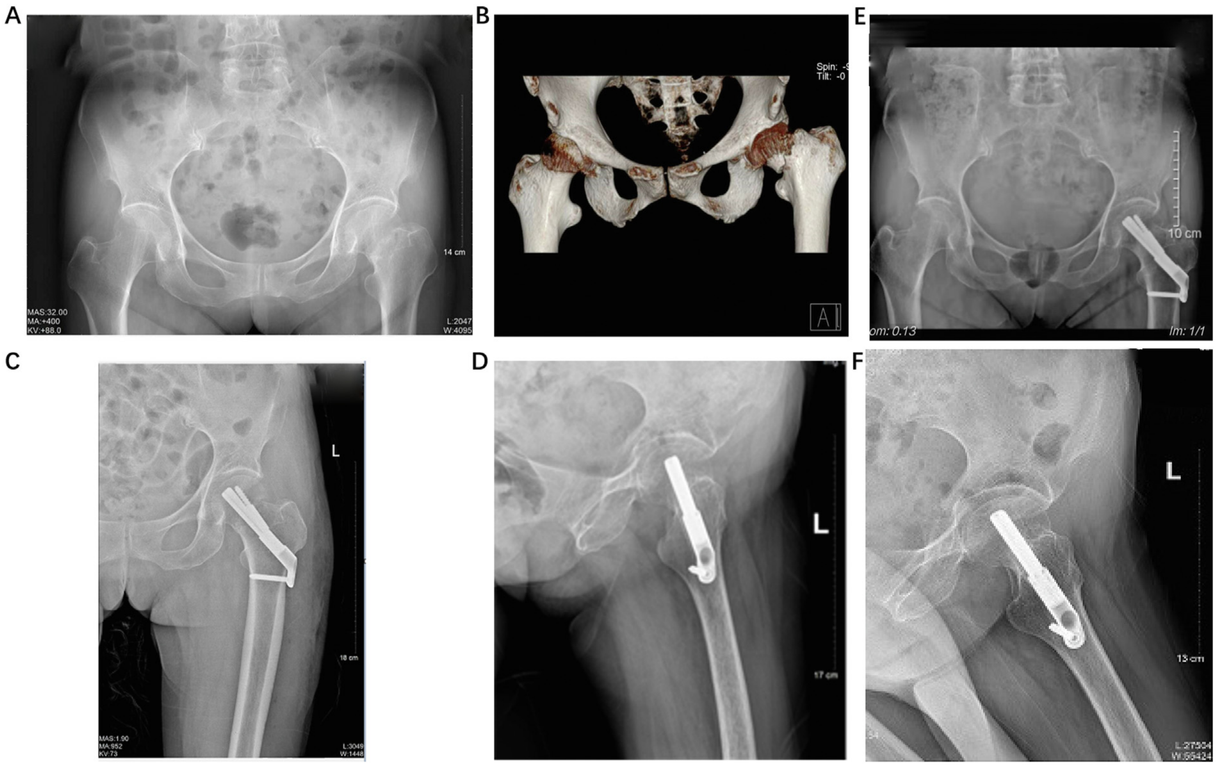

Fig. 1. A 64-year-old female patient in the Femoral Neck System (FNS) group with a left femoral neck fracture caused by falling (Garden type III) (Pauwels angle: 51°). (A) Preoperative anteroposterior X-ray image of the pelvis. (B) Preoperative 3D computed tomography (CT) image. (C) Anteroposterior image at 2 days after the operation. (D) Lateral X-ray image at 2 days after the operation. (E) Image at 13 months after the operation. (F) Lateral X-ray image at 13 months after the operation, showing no significant change in Garden alignment index at the fracture end. The fixation was in a good position without significant withdrawal or penetration into the hip joint.

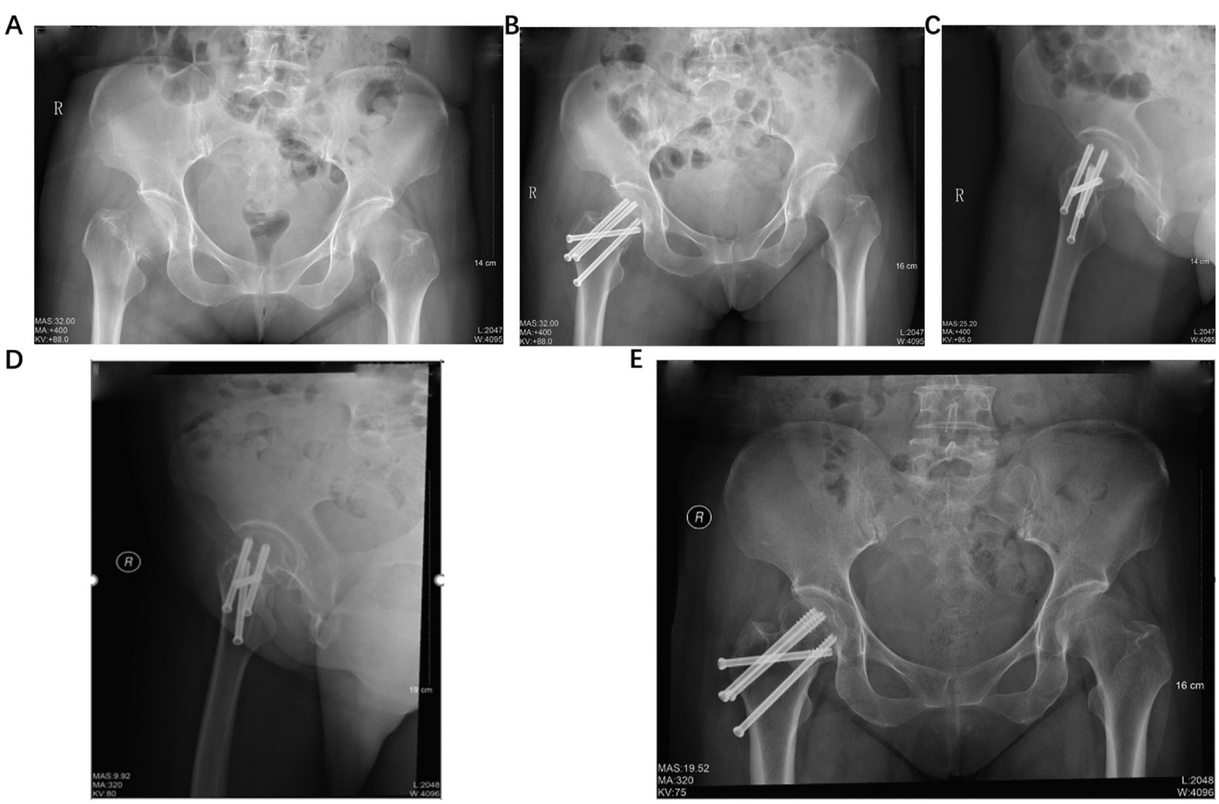

Fig. 2. A 51-year-old female patient with a right femoral neck fracture caused by falling (Garden type III) (Pauwels angle: 65°). (A) Preoperative plain image of the pelvis. (B) Plain image of the pelvis at 2 days after the operation. (C) Lateral X-ray images at 2 days after the operation. (D) Lateral X-ray image at 13 months after the operation, showing continuous bone cortex and union of fracture, with no femoral head necrosis or internal fixation failure. (E) Plain image of the pelvis at 13 months after the operation. A mild withdrawal was observed in the four screws (<10 mm).

scores [27]. Lutnick et al. [20] showed that according to the hip Harris score, SF-36 score, and European QOL disability score, collapse or shortening of the femoral neck is associated with poorer overall outcomes, which is the major cause of secondary operation. Such association could still be observed even when the femoral neck is shortened by 5 mm but is especially evident when the shortening is >10 mm [20]. In this study, shortening of the femoral neck was observed in patients of both groups, but the incidence of shortening by >10 mm was 11% and 23% in the FNS and control groups, respectively. The dynamic compressing on the fracture end applied after shortening the femoral neck favored the healing of the fracture, but the postoperative fracture healing time was not significantly different between the two groups. Still, promoting bone union and preventing femoral head necrosis while reducing the shortening of the femoral neck as possible remains a challenge, and no best method has been reported yet. This study showed that the incidence of the short femoral neck, withdrawal of internal fixation, and necrosis of the femoral head were significantly lower in the FNS group, while the hip joint functions and hip Harris scores were significantly higher in the FNS group than in the control group, suggesting that the FNS could achieve better anti-vertical shear force biomechanics, as supported by recent studies [15,17,28,29].

The limitations of this study include the retrospective nature of the study, limited data and follow-up, and substantial selection bias. The sample size of this study was also relatively small, which could reduce the statistical power. In addition, only patients with Pauwels III fractures were included in this study. The more vertical the fracture line is the higher the failure rate for femoral neck fracture theoretically, which could influence the study's findings.

In summary, this study demonstrates that for the internal fixation of unstable femoral neck fracture in young and middle-aged patients, FNS has the advantage of being minimally invasive and easy to operate. In addition, FNS apparently has a higher capability of anti-shear force, the fixation appears stronger, and the incidence of postoperative femoral neck shortening, internal fixation withdrawal, and fixation failure is lower than when using four cannulated screws. Hence, the FNS apparently results in a better recovery of the hip joint functions after the operation. The findings suggest that FNS treatment could achieve good clinical efficacy, might be one of the ideal treatments for Pauwels III femoral neck fracture, and could be used as a new method for treating such patients.

Ethical

This retrospective study included patients with newly occurred type Pauwels III femoral neck fracture treated at the Department of Orthopedics of Mindong Hospital of Fujian Medical University between January 2017 and February 2021. This study was approved by the Ethics Committee of the Mindong Hospital of Fujian Medical University ([2021] Ningmin Medical Ethics Review No. 0325-40). The requirement for individual consent was waived by the committee. The patient was given a comprehensive agreement on the use of academic information at the time of admission, including the type of treatment, progress of treatment and all data obtained during treatment, and the manuscript contained no identifiable patient information.

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Declaration of competing interest

All authors declare that they have no competing interests.

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