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Comparison of outcomes of Salter and Varus osteotomies in the treatment of Legg-Calve-Perthes Disease: a retrospective cohort study

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Abstract

Background Legg-Calve-Perthes Disease (LCPD) is described as idiopathic avascular osteonecrosis of the capital femoral epiphysis in pediatrics. LCPD is usually present in children between 2 and 15 years and happens more frequently in boys more than girls; this study aims to compare the outcome of two surgical methods in treating LCPD.

Methods We included sixty patients with unilateral LCPD who underwent Salter or femoral varus osteotomy from 2007 to 2017. Patients' claudication, pain, leg circumference, range of motion, lever arm ratio (LAR), neck shaft angle (NSA), migration index, vertical distance, and the presence of teardrop sign, sagging rope sign, and Trendelenburg sign were evaluated five years after surgery.

Results The mean neck shaft angle, the lever arm ratio, migration index and, sagging rope sign incidence in patients undergoing femoral varus osteotomy were significantly lower than those undergoing Salter surgery; the thigh circumference was higher in patients undergoing femoral varus osteotomy than those undergoing Salter osteotomy.

Conclusion There were significant differences in biomechanical indices of hip and acetabulofemoral in salter and femoral varus osteotomy; the results of the current study are highly suggestive of prioritizing femoral varus osteotomy to Salter surgery.

Keywords Perthes disease, Salter osteotomy, Femoral varus osteotomy

Introduction

Legg-Calve-Perthes Disease represents idiopathic or avascular osteonecrosis of the capital femoral epiphysis of the femoral head in pediatrics [1]. Age and the degree of involvement are two determining factors that affect the success rate of different treatments for LCPD; for example in patients younger than six having more than 50% involvement of femoral capital epiphysis, surgical and non-surgical methods both have satisfactory results, but in children older than six having more than 50% involvement and some degrees of head subluxation, surgical technique seem to be more effective [2].

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Treatment of LCPD includes surgical and non-surgical methods; various treatments from tractions and casting to advanced surgical methods have evolved over years to increase quality of life, reduce osteoarthritis risk, and restore the range of motion in affected joints [3].

All surgical methods used for LCPD management intend to reshape the joint with appropriate angles in bones to improve movement and provide relief with the least possible damage to the epiphyseal area of femur in hip joint. Various surgical methods exist for LCPD management; Varus osteotomy, femoral osteotomy, pelvic osteotomy, pelvic osteotomy, and pelvic osteochondroplasty are some of the commonly done surgeries. Varus osteotomy is used when there is significant femoral head deformity and joint stability is a priority in LCPD management. Femoral osteotomies are done when hip deformities or severe lateralization of femoral head is present. Pelvic osteotomy is commonly used in patients when improving acetabular coverage is prioritized. Triple osteotomy is reserved for older patients with significant deformities and severe instability in multiple planes. Osteochondroplaties are done for patients where there is significant cartilage damage or femoral head irregularity which reduces the success rates of aforementioned surgeries [4].

Among the mentioned surgical methods, Salter innominate osteotomy (SIO) and femoral varus osteotomy (FVO) are the most commonly used procedures for LCPD management. And previous studies claim that considering that both SIO and FVO have benefits and disadvantages, both have promising long term outcomes in patients [5]. The current study aims to compare clinical and radiographic outcomes, femoroacetabular containment, and mechanical load on femoral capital epiphysis of Perthes' disease patients aged between six and ten with more than 50% epiphyseal involvement and Catterall classification three and four, undergoing FVO and SIO.

Materials and methods

Study design

This retrospective cohort study reviewed all patients aged six to ten years old diagnosed with Perthes' disease who underwent FVO or SIO surgeries between 2007 and 2017 and compared the radiological and clinical outcome of these surgical methods. FVO and SIO procedures were performed at our pediatric referral hospital for tertiary care (Imam Khomeini Hospital Complex (IKHC), Tehran, Iran) by the same surgical team and protocol. They were followed for a minimum of five years after surgery [6]. Medical records and clinical and surgical information were collected from diagnosis to recovery after surgery. All procedures performed in studies involving human participants were in accordance with the ethical standards of the national research committee and with the 1964 Helsinki Declaration and its later amendments. The Ethics Committee of Tehran University of Medical Sciences approved this study.

Inclusion and exclusion criteria

The inclusion criteria were: (1) LCPD patients aging between six and ten years old, (2) informed parental consent, (3) More than 50% involvement of the femoral head (assessed on the anteroposterior (AP) pelvic radiography of hip in anatomical and 30-degree abduction position (Herring types B, B/C, C)), and (4) Subluxation of the femoral head in the acetabulum.

Exclusion criteria were: (1) Bilateral disease, (2) Previous hip surgery, (3) Severe ROM limitations, (4) Not having complete acetabular containment in the abducted hip radiograph, (5) combined surgery of acetabulum and femur, 7. Congenital disorders (i.e. hemophilia, thalassemia, and cerebral palsy).

According to Waldenstrom's classification, all of the patients were in the initial phase or early fragmentation phase at the time of surgery [7].

Surgical technique

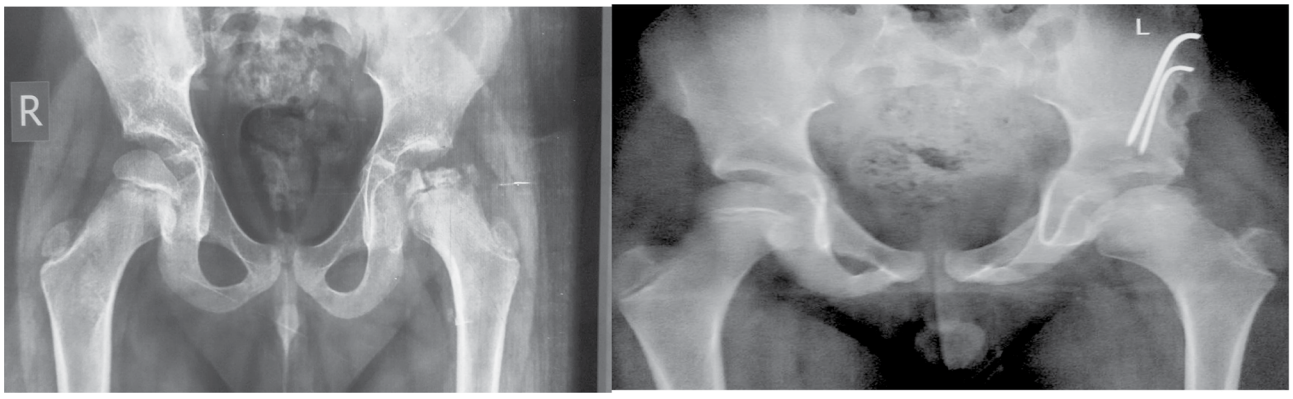
Both procedures were done after general anesthesia was performed for the patients. The surgical method described by Salter et al. in 1961 was used for SIO [8]. In this procedure, the corticocancellous bone graft from the iliac crest is inserted in the osteotomy site and fixed with two Kirshner wires to improve the superolateral coverage of the femoral head [9].

FVO was performed by the technique of medial close wedge osteotomy and then was fixed with dynamic compression plates (DCP). Based on the size of the femur, the DCPs were sized 3.5 or 4.5 millimeters and fixed at a varus angle of nearly 25°. In both groups, post-operative spica casting was performed and after 6 weeks (presence of a callus), the cast was removed and the patients was permitted to begin exercising joint movement as well as partial weight-bearing with crutch. After confirming union on follow-up radiographs, full weight bearing was allowed. An example of Pre-op and post-op radiographies of both procedures are presented for better illustration of FVO and SIO surgeries (Figs. 1A and B and 2A and B).

Outcome measures

Follow-up visits were scheduled at 2 weeks, 6 weeks (removing the cast), and monthly until 6 months, 12 months, and annually following surgery. In the final follow-up, patients underwent a physical exam to determine hip ROM, hip abduction, thigh circumference, and complications. Antero-posterior (AP) and Lauenstein lateral radiographs of the hip taken prior to surgery were used to determine the stage of the disease and the extent of femoral head involvement. X-ray radiographs of the

Figs. 1 **A**, **B** Pre-op and post-op X-rays of a patient undergoing femoral varus osteotomy (FVO)



Figs. 2 **A**, **B** Pre-op and post-op X-rays of a patient undergoing salter innominate osteotomy (SIO)

patients were obtained using a standard protocol at the same radiology department. In addition, the most recent radiograph for each participant was used to evaluate the radiological outcomes of the disease. An expert musculoskeletal radiologist determined the radiographic measurements on the standard standing hip AP radiographs including lever arm ratio, sagging rope sign, teardrop shape, neck shaft angle, migration index, center edge angle, vertical distance.

Definitions

The migration index or epiphyseal extrusion index was introduced be Green et al. in 1981 as a prognostic indicator [10]. It is measured by dividing the part of the femoral head that is lateral to the Perkins line by total femoral width. Lever arm ratio was used as an index of present pressure to the head of the femur (Fig. 3). Lever arm ratio is calculated by dividing the bodyweight lever arm (L) by the abductor lever arm (A); normal pressure to the femoral head is three times the body weight in cases when lever arm ratio equals to 2.5. Changes in the lever Arm ratio can affect the joint reaction force, as people with femoral neck shortening (shorter arm and thus, higher lever arm ratio) have a higher level of pressure on the hip joint. Central edge angle is calculated by drawing a line from the center of femoral neck to most lateral part of the acetabulum in the radiologic eyebrow. Then, a line perpendicular to the transverse axis of the pelvis is drawn and the angle between two lines is measured. A CEA less than 25 is considered to be a sign of insufficient coverage (Fig. 4).

Sagging rope sign is known as a visible line connecting the inferior border of the lateral side of femoral neck to the superior border of the medial side of femoral neck. This sign commonly entails severe epiphysial damage and therefore, severe growth plate damage (Fig. 5).

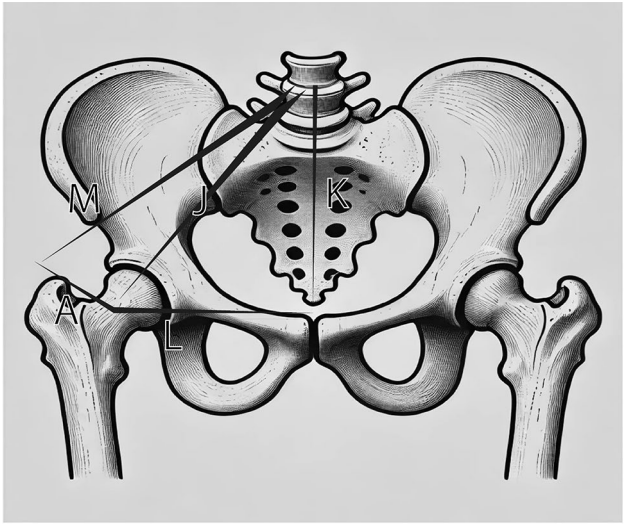


Fig. 3 K is defined as the body weight minus the weight bearing leg, M is defined as the abductor muscle force repelling K, and J is the total joint reaction force. Lever-arm ratio is calculated by dividing L by A

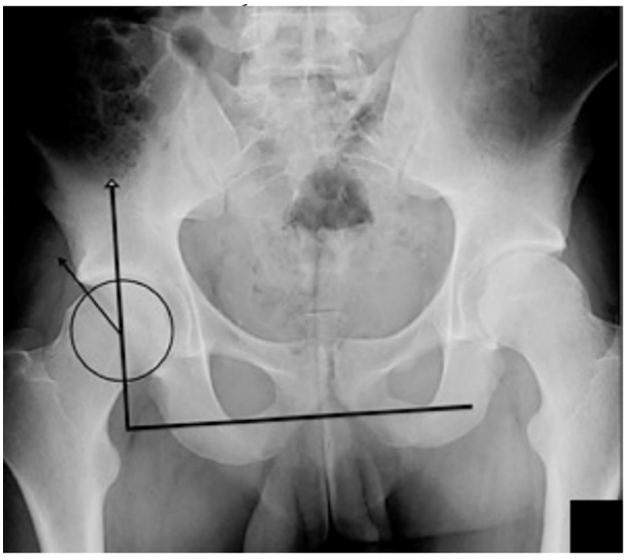


Fig. 4 The angle between the line perpendicular to the transverse pelvis line and the most lateral acetabular part connected to the femoral neck center is known as the central edge angle

Neck-shaft angle (NSA) is an angle formed between the longitudinal axis of the femoral neck and that of the femoral shaft; normally, values between 125 and 135 are considered normal. This index varies between different ethnicities and changes with age (Fig. 6). Vertical distance is measured by measuring the vertical distance between two lines drawn perpendicular to a line drawn along the anatomical axis of the femur, one from the center of the femoral head and the other from the tip of the greater trochanter (Fig. 7).

Fig. 5 Sagging rope sign is known as the radiopaque line visible between the inferior border of the lateral part of femoral neck connected to the superior border of the medial part of the femoral neck; this sign is commonly associated with severe epiphyseal damage

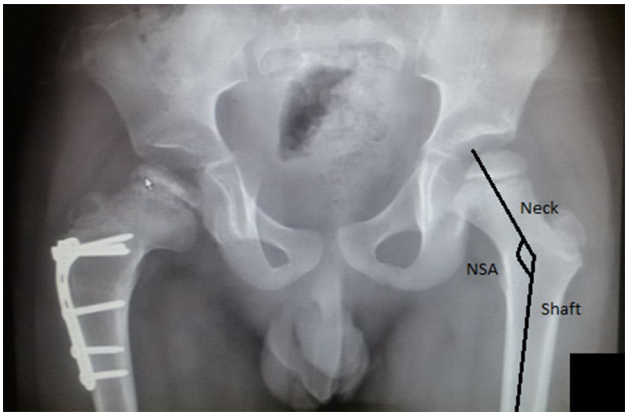


Fig. 6 Neck shaft angle (NSA) is measured by drawing a line from the longitudinal axis of the femoral neck and that of the femoral shaft

Data collection

Baseline characteristics including age at disease onset, sex, side of the pathology, and age at diagnosis and surgery, claudication status, level of pain, leg circumference, range of motion (abduction, internal rotation, and external rotation)were extracted from the patients' medical profile.

Demographic characteristic

The mean age of patients was 7.65 years. Finally, 60 patients were analyzed, including 6 (10%) girls and 54 (90%) boys. 28 (46.6%) patients underwent SIO, and 32 (53.4%) patients underwent FVO. The mean follow-up was 6.7 years (range: 5–16) (Table 1).

Statistical analysis

The IBM SPSS software (version 26) was used to analyze the data (IBM, USA). Quantitative data were tested for normality using the Kolmogorov–Smirnov (KS) test. Percentages and frequencies were used to describe qualitative variables and mean, standard deviation, median, and

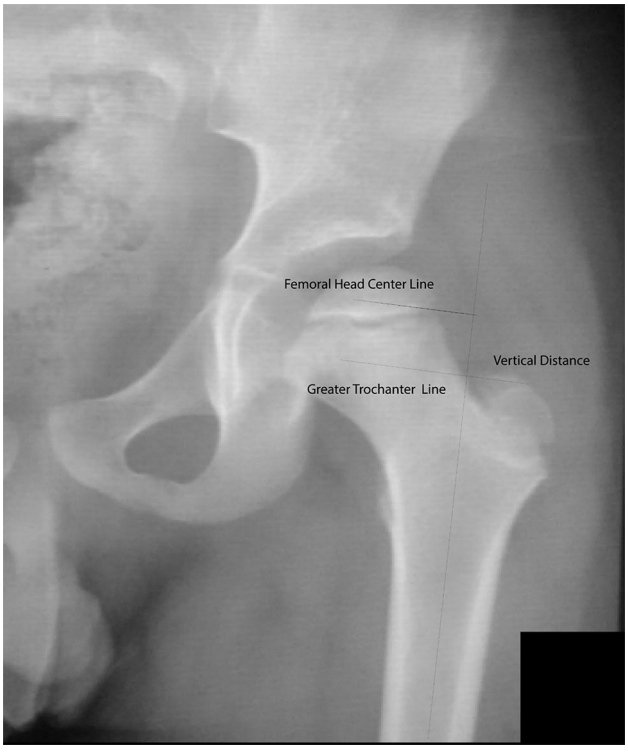


Fig. 7 Vertical Distance is measured by measuring the vertical distance between two lines drawn perpendicular to a line drawn along the anatomical axis of the femur, one from the center of the femoral head and the other from the tip of the greater trochanter

Table 1 Comparison of demographic and surgical characteristics between the FVO and SIO groups

Demographics and Surgical characteristics	FVO (*N* = 32)	SIO group (*N* = 28)	*P*-value
Age (years)	7.4 ± 1.9	7.9 ± 2.0	0.369
Sex	28	26	0.49
• Boy	4	2	
• Girl			
Laterality	17	14	0.81
• Right	15	14	
• Left			
BMI (kg/m^2)	23.3 ± 1.3	23.7 ± 1.7	0.3
Herring classification	11	10	0.727
• B	9	10	
• B/C	12	8	
• C			
· **Follow-up** (Years)	6.5 ± 1.3	6.9 ± 0.4	0.258

Abbreviations * Statistically significant

range of changes were used to describe the quantitative variables. Chi-Squared and fisher's exact tests were used to compare categorical variables influencing treatment outcomes, for continuous variables, Student's T-test was used. a P-value (two-sided) less than 0.05 was considered statistically significant.

Table 2 Comparison of outcome measures between the FVO and SIO groups

Variable	FVO group (*N* = 32)	SIO group (*N* = 28)	*P*-value
Clinical outcomes			
Postoperative Trendelenburg sign	25 + 7 -	23 + 5 -	0.666
Thigh circumference	Healthy: 34.1 Operated: 32.7	Healthy:40.8 Operated:38.5	0.016*
Radiological outcomes			
Teardrop • Normal • Abnormal	27 5	22 6	0.574
Sagging rope sign • Negative • Positive	23 9	12 16	0.023*
Neck shaft angle (NSA) • Non-operated side • Operated side	13.0 11.8	14.9 19.3	< 0.000*
Migration index • Non-operated side • Operated side	11.81 13.02	14.89 19.32	0.017*
Lever Arm Ratio • Healthy side • Operated side	2.4929 2.3871	2.3563 2.4679	0.036*

Abbreviations * Statistically significant

Results

Clinical finding

At the latest follow-up, 48 patients had a negative Trendelenburg sign, five patients in the Salter osteotomy group, and seven patients in the SIO group had a positive Trendelenburg sign (P: 0.666).

In both groups, thigh circumference was lower on the surgical side compared to normal side; average thigh circumference in the SIO group was 40.81 cm in healthy side and was 38.52 cm in operated side, in FVO group thigh circumstance was 34.11 cm in normal side and in was 32.71 cm the healthy side; analysis shows that thigh circumference reduction was significantly higher in SIO cohort compared to the FVO cohort (P: 0.016 and SD: 0.3501, Table 2).

Radiographic findings

11 patients had an abnormal teardrop sign, six of whom underwent salter osteotomy and five underwent femoral varus surgery. Among 49 patients with a normal teardrop, 22 patients belonged to the SIO cohort and the rest were in the FVO cohort. There was no significant relationship between teardrop and type of surgery. Sagging rope sign was positive in 25 patients, 16 of which were in the SIO group and nine were in the FVO group (OR: 3.4, 95% CI: 1.1–9.9, P: 0.023 ,Table 2).

The mean neck shaft angle (NSA) in SIO group reduced from 135.68 to 132.79 and in the FVO cohort reduced from 134.86 to 120.10. considering these results, the type of surgery had a significant effect in neck-shaft angle ($P < 0.000$). In SIO patients, NSA was closer to normal than in FVO group.

Migration index in SIO group changed from 11.81 to 19.32% and in FVO group changed from 14.89 received to 13.02%; our results show that the type of osteotomy has a significant effect (P: 0.017).

Our study results show that the type of surgery affects Lever Arm Ratio in LCPD patients; Lever Arm Ratio in SIO patients changed from 2.35 to 2.46 and in FVO patients went from 2.49 to 2.38, which means SIO might cause an increase in Lever Arm Ratio and FVO might decrease it.

Discussion

Our study results showed that when comparing the two groups, the patients in the FVO group had better results; lower sagging rope sign, less reduction in hip circumference, and reduction in NSA, LAR, and migration index compared to SIO patients in whom the three aforementioned indices increased.

The therapeutic method in LCPD has different targets including reducing pressure on the femoral head, increasing range of motion, reducing pressure on external and internal rotator hip muscles, and increasing quality of life. A wide range of treatment methods are suggested for LCPD, some of which focus on medical and conservative approaches, and some of which concentrate on surgical procedures like osteotomies, most experts use both of them [11]. Currently, surgical techniques by cutting and fusing bone parts together have an important role; Saving femoroacetabular containment and weight reliving or reducing pressure on the femoral head are two confirmed prognostic factors in treatment, reduction of recovery time, and long-term side effect of LCPD.

Surgical methods save femoroacetabular containment more than the other methods, but the preferred osteotomy techniques must reduce pressure on damaged epiphyses of the femoral head and reduce the force that muscles exert on the hip so it can save the spherical shape of the femoral head. In a systematic review that aimed to compare surgical and non-surgical methods to treat Legg-Calve´-Perthes disease (LCPD) by Saran et al. the authors found that surgical techniques including SIO and FVO are preferred treatment methods for patients over six years of age [12]. Although surgical procedures are effective but complications including hip pain (7–31%), leg length discrepancy (4–33%), abductor insufficiency (4–25%), restricted hip movement (4–25%), and surgical procedure scar make the choice of surgery a hard one [12].

Herring et al. evaluated five different treatment methods for Perthes, the result of that study revealed long-term outcome of surgical methods including salter, varus femoral osteotomy is better than medical treatment, and there is no significant difference in the results of both surgical methods [13].

Lever Arm Ratio is a biomechanical index in orthopedics used to evaluate pressure on the femoral head in the stance phase; an increase in Lever Arm Ratio will be associated with abductor muscle hypertrophy. Our results show that Lever Arm Ratio in the SIO group has a significant increase compared to the femoral varus osteotomy group and the healthy side of the SIO. Coxa breva or Shortening of the femoral head and abductor's arm which present as a Sagging rope sign in the current study has an important role in determining lever arm ratio and was more frequent in a patients treated with Salter osteotomy; this can be a good explanation for higher Lever Arm Ratio in salter group comparing femoral varus osteotomy. This result is in agreement with the results of previous studies that compared different osteotomies for LCPD [14–18].

Reducing strong contraction in abductor muscles of the hip is one of the outcomes following femoral varus osteotomy, this index is evaluated by the Trendelenburg sign, considering there is no significant difference in the Trendelenburg sign between the two groups, it means there is no muscle failure in patients. In 1977, Moberg et al. compared clinical and radiographic outcomes of Salter and femoral varus osteotomy, results showed no significant difference in all the variables except femoral head coverage in both groups, in the Salter group coverage of the femoral head was more than femoral varus [19].

Changes in the lower limb are a huge concern after osteotomy surgeries and must be kept in mind; Remodeling of the Neck shaft angle (NSA) is an important point that must be considered in the osteotomy procedure in femoral varus osteotomy. In the current study, we use thigh circumference as a predictor that reflects atrophy of the flexor and abductor muscles of the hip; in our study the reduction in hip circumference was significantly higher in SIO patients compared to FVO patients. Terjesen et al. evaluated 70 patients older than 6 years to compare postoperative outcomes of femoral varus osteotomy and physiotherapy after 5 years, result of that strongly confirmed effectiveness of femoral varus osteotomy in femoral head. The findings of former studies were compatible with ours about the effectiveness of surgical methods and better outcomes of femoral varus surgery versus Salter osteotomy.

Our study has some limitations; the retrospective nature of our study and non-randomized patient recruitment makes our study prone to bias. Also, considering that the patients' age ranged from six to ten and the

follow-up duration for our study was at least five years, the results might be biased since the femur bone might undergo an ovalization process during the growth process, which might change the measured indices and bias our study results.

Conclusion

Our study results showed that in children aged six to ten suffering from LCPD, when comparing the SIO and FVO procedures, patients undergoing SIO had better results; the patients in the SIO group had significantly higher sagging rope signs, higher reduction in hip circumference, and an increase in NSA, LAR, and migration index compared to patients undergoing FVO that had a reduction in LAR, NSA, and migration index. This means the FVO surgery led to a lower force on the hip joint, had better femoroacetabular containment, and less muscular atrophy.

Author contributions

P.M, MT.PF, D.S, and S.K were involved in interpretation and collecting of data, and drafting and editing the manuscript. T.B, M.M and A.M involved in writing, editing and preparing the final version of manuscript. All authors reviewed the paper and approved the final version of the manuscript.

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Data availability

The datasets used and analyzed during the current study will be available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the national research committee and with the 1964 Helsinki Declaration and its later amendments. The Ethics Committee of Tehran University of Medical Sciences approved this study and Informed consent was obtained from all patients and their legal guardian for participation in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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