Comparison of the clinical effects of arthroscopic surgery vs. open surgery for grade II gluteal muscle contracture in adults

TING ZHANG, SIYUE XU, HAOPENG LI, XIJING HE and FENG ZHANG

Department of Orthopaedic Surgery, The Second Affiliated Hospital of Xi'an Jiaotong University, Xi'an, Shaanxi 710004, P.R. China

Received November 21, 2017; Accepted May 1, 2018

DOI: 10.3892/etm.2018.6162

Abstract. The aim of the present study was to compare the clinical effects of arthroscopic surgery with open surgery for grade II gluteal muscle contracture (GMC) in adults and to discuss the indication and technique for arthroscopic GMC release. The clinical data of 113 adult patients with grade II GMC between 2011 and 2016 was retrospectively collected. Among these patients, 72 patients received open surgery and 41 received arthroscopic surgeryy. The 2 groups were compared in terms of surgical duration, incision size, blood loss, hospital stay, analgesic dose and ranking of postoperative functions and effects. Mean surgical duration was significantly greater in the arthroscopic surgery group (P<0.001). Mean incision size, blood loss, hospital stay and analgesic dose were significantly lower in the arthroscopic surgery group compared with the open surgery group (P<0.001). There was no significant difference observed regarding the ranking of functions and effects between the two groups. These results suggest that existing untreated patients with GMC having low-severity (grade II) contractures of limited area are suitable for arthroscopic surgery. The advantages of arthroscopic GMC release include limited surgical trauma, a small incision, low blood loss and fewer surgical complications.

Introduction

Chinese children have a very high incidence of gluteal muscle contracture (GMC) due to the extensive use of intramuscular injections over the last century (1,2). Since an association was found between the intramuscular injection of benzyl alcohol and GMC (3), aetiological prevention has led to a significant reduction in new cases of GMC (2,4,5). However, there are still numerous patients with untreated GMC who have not received an early diagnosis or treatment due to a lack of awareness of the disease.

Currently, adult patients with untreated GMC have a relatively less severe form of GMC. According to the GMC classification criteria of Zhao *et al* (1,6), most of them were ranked as grade II GMC. Most patients first experience the inconvenience of GMC in work and life during adulthood. Since these patients are generally well educated, they often use the internet and other channels to acquire GMC-related information. This patient population has a strong desire for treatment with clear goals. They expect to achieve a good treatment effect without an effect on their appearance.

Conservative treatment (e.g., manual massage and functional exercises involving crouching with the knees close together) can be used to treat grade I GMC, while open surgery is required for grade III GMC. At present, two surgical options are available for adult patients with grade II GMC including open GMC release and arthroscopic GMC release. These two surgical options have different characteristics. Open surgery is considered to be reliable and effective but it may cause large trauma and high incidences of postoperative complications. Arthroscopic surgery has a limited effect on appearance and results in a small incision, reduced trauma and fewer complications. However, it has a relatively lower rate of release and has the possibilities of insufficient release. To our knowledge, there has been no previous report comparing the two surgical options for adult patients with grade II GMC. Therefore, the aim of this study was to compare the clinical effects of arthroscopic surgery with open surgery for grade II GMC in adults and discuss the indication and technique for arthroscopic GMC release.

Patients and methods

Patients. The study was approved by the ethics committee of The Second Affiliated Hospital of Xi'an Jiaotong University (Xi'an, China) and conducted in accordance with the Declaration of Helsinki. Signed consent was obtained from each patient. From 2011 to 2016, 113 adult patients with grade II GMC who underwent surgery at our department were included in this study. GMC is diagnosed primarily by history and some important physical examinations (6). Patients with hip pain, radiographic evidence of hip dislocation or hip dysplasia by X-ray examinatio, history of hip infection, clinical

Correspondence to: Dr Xijing He, Department of Orthopaedic Surgery, The Second Affiliated Hospital of Xi'an Jiaotong University, 157 Xiwulu, Xi'an, Shaanxi 710004, P.R. China
E-mail: hexijing88@yeah.net

Key words: gluteal muscle contracture, minimal invasive, arthroscopic surgery, release

manifestations of neurological damage, grades I and III GMC were excluded. Patients with gluteal soft tissue tumours and gluteal compartment syndrome were also excluded. The clinical symptoms of GMC include history of repeated intramuscular injections into the buttocks, abduction and external rotation with limited flexion and adduction of affected hip, unable to bring knees together during squatting, sits in frog-leg position, out-toeing gait/cannot walk in straight line, snapping sound while squatting, unable to cross or overlap legs, knee crepitus, and anterior knee pain (6). The signs of GMC include Ober's sign positive, active flexion test positive, reverse Ober's sign positive, palpable snapping sound while squatting, pelvic tilt toward severe side, compensatory scoliosis, apparent leg length discrepancy (affected leg looks longer), flattened or cone-shaped buttock, and dimpling of skin in the buttock area (6). The severity of GMC was according to a previous classification method of Zhao *et al* (6). Based on the GMC classification criteria of Zhao *et al* (6), all the patients were ranked as grade II, with no grade III or I cases by two trained and experienced authors. Among these patients, seventy-two patients were treated with open GMC release (open surgery group) and forty-one patients were treated with arthroscopic surgery (arthroscopic surgery group). All the surgical procedures were completed by the same surgeon (Siyue Xu). Among these patients, there were 34 men and 38 women with a mean age of 22.39±3.80 years in the open surgery group and 23 men and 18 women with a mean age of 23.05±4.67 years. In both groups, patients had bilateral contracture. The two groups of patients did not differ significantly regarding age and gender, age at disease onset and mean postoperative followup time (all P>0.05; Table I).

Patient interviews showed that 96 (85%) had received repeated intramuscular injections of penicillin using benzyl alcohol as a solvent before the age of 6 years, while 17 (15%) were uncertain about their history. Five cases had undergone conservative treatment such as manual massage and functional exercise by crouch with both knees close to each other. All the patients had dysfunctions when crouching and sitting cross-legged and 97 experienced hip snapping.

Surgical procedures. Open surgery: The patient was placed in the lateral decubitus position. A surgical incision, generally 4-6 cm long, was made in the lower middle 1/3 of a line between the trochanter major and the posterosuperior iliac spine (Fig. 1) (1,7). The thinned superficial fascia was cut open to expose tough white contractile bands consistent with the direction of the muscle fibres. The contractile bands were cut into two parts: The tensor fasciae latae anterior-exterior to the incision and the gluteus maximus and medius posterior-inferior to the incision. In cases of grade II GMC, the tough white fibrotic cords are relatively limited and generally do not exceed the gluteus maximus and medius. A blade or electrotome was placed perpendicular to the direction of the gluteal muscle fibres, and the function of the adductors was significantly improved immediately after the white tough fibrous cords and thickened fascia latae were cut. During the surgery, the contractile bands were cut and allowed to retract freely without removal. Ober's test was conducted during surgery, with extension and flexion of the knee and hip joints. After satisfactory hip adduction at different extension and flexion angles was confirmed, haemostasis was carefully conducted, and the wound was closed.

Arthroscopic surgery: The patient was placed in the lateral decubitus position. The outline of the trochanter major was marked before surgery. Bilateral disinfection, draping and surgery were performed. During surgery, 3,000 ml of normal saline supplemented with 1 ml of 0.1% epinephrine was used for continued gravity perfusion and irrigation, which facilitated intraoperative haemostasis and maintained a clear surgical field.

Surgical portals were established at the lower middle 1/3 of the line between the trochanter major and the posterosuperior iliac spine (Portal A) and the tip of the trochanter major (Portal B). The position of Portal B was adjusted based on the position of the contractile bands determined before surgery and the expected release area. For instance, if the contractile bands were relatively posterior, then Portal B could be adjusted posteriorly along the horizontal line of the trochanter major. Portal A was the viewing portal, and Portal B was the working portal (Fig. 2). The subcutaneous tissue was bluntly dissected, and any subcutaneous adipose tissue that blocked the surgical view was properly resected by arthroscopy shaver. The contractile bands were identified using arthroscopy. The contractile bands usually resembling scar tissue in texture with a white colour were markedly different from normal muscle tissue (Fig. 3). A radiofrequency device was used to cut the contractile bands around the trochanter major without cutting the muscle tissue, and haemostasis was conducted during release (Figs. 4 and 5). Ober's test was conducted, and the sliding of contractile bands was monitored with arthroscopy to determine the extent of release and the position of the residual contractile bands. If passive adduction was limited in the flexed position, it was generally necessary to release the contractile bands posterior to the trochanter major. If adduction was limited near the fully extended position, it was generally necessary to release the contractile bands anterior to the trochanter major. The extent and depth of the release were adjusted based on Ober's test and endoscopic observations. The release was performed until there was no snapping in passive flexion, adduction and internal rotation of the hip and these motions were no longer limited. The typical release procedure for grade II GMC was as follows: First, the contractile bands were released around the trochanter major for the tensor fascia latae and gluteus maximus anterior to the trochanter major; then, the contractile bands were released for the gluteus maximus and medius posterior to the trochanter major. The position of the sciatic nerve was kept in mind, and efforts were made to ensure that the release was not too posterior or deep. If the contractile bands were relatively posterior, making surgery difficult, the hip could be flexed to slide the contractile bands anteriorly. Before wound closure, as much subcutaneous fluid as possible was drained through a drainage tube.

Postoperative treatments. Open surgery group: Negative pressure drainage was routinely performed, and the drainage tube was removed when the 24-h unilateral drainage volume was less than 20 ml. Pressure dressings were applied over the wound for 3 days after surgery. The patients generally began functional exercises such as crouching with the knees close together and walking in a straight line on day 3 after surgery. Functional exercises were generally performed 3-5 times a day for 20-30 cycles each time based on the patient's tolerance.

Table I. Baseline characteristics of each group.

Characteristic	Open surgery (n=72)	Arthroscopic surgery (n=41)	P-value
Age, years	22.39±3.80	23.05±4.67	0.42
Sex, n			0.36
Male	34	23	
Female	38	18	
Mean follow-up time, years	2.23±0.31	2.10±0.23	0.09
Age at disease onset, years	6.25±1.11	6.43±1.52	0.58

Data is presented as the mean ± standard deviation.

Figure 1. Incision of open gluteal muscle contracture release.

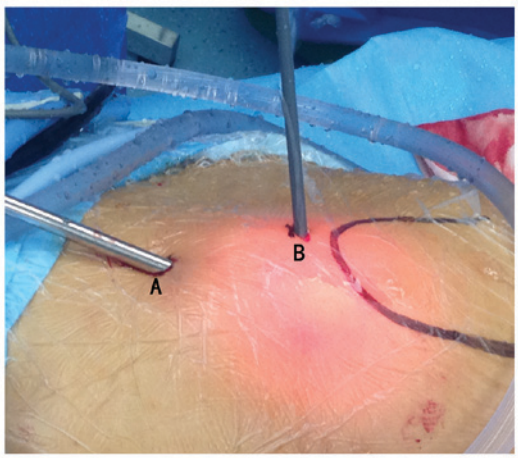

Figure 2. Intraoperative photograph showing portals for arthroscopic gluteal muscle contracture release. A indicates portal A (the viewing portal), B indicates portal B (the working portal). The outline of the trochanter major was marked.

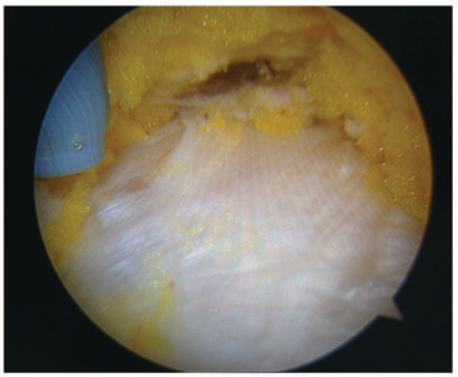

Figure 3. Intraoperative photograph of arthroscopic gluteal muscle contracture release. The contractile bands were exposed after subcutaneous tissue that blocked the surgical view was resected.

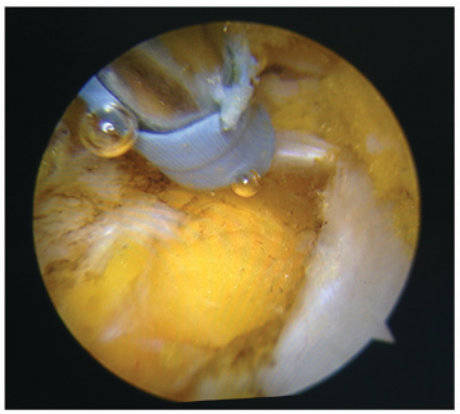

Figure 4. Intraoperative photograph of arthroscopic gluteal muscle contracture release. A radiofrequency device was used to cut the contractile bands.

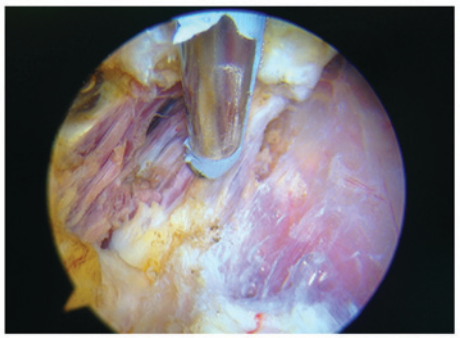

Figure 5. Intraoperative photograph of arthroscopic gluteal muscle contracture release. A radiofrequency device was used to release the contractile bands scattered between muscle bundles.

Arthroscopic surgery group: Negative pressure drainage was routinely performed, generally for no more than 48 h. After placement of the drainage tube postoperatively, we squeezed the surroundings of the wound and changed the direction of drainage tube to discharge the arthroscopic fluid via the drainage tube as much as possible. The drainage tube was removed when the 24-h unilateral drainage volume was less than 20 ml. No pressure dressings were applied over the wound after surgery. The patients began functional exercises such as crouching with the knees close together and walking in a straight line as soon as the drainage tube was removed. The functional exercises were generally performed 3-5 times a day for 20-30 cycles each time based on the patient's tolerance.

If any patient in either group experienced intolerable pain after surgery, oxycodone and acetaminophen was orally

Table II. Comparison of surgical duration, incision size, blood loss, hospital stay and analgesic dose.

Surgery group	Surgical duration (min)	Incision size (cm)	Blood loss (ml)	Hospital stay (days)	Analgesic dose (mg)
Open surgery (n=72)	42.89±9.17	10.23±1.45	214.51±34.43	9.30±1.98	6.83±4.80
Arthroscopic surgery (n=41)	62.68±8.88	3.07±0.26	76.83±21.53	6.12±0.81	3.29±3.08
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Data are presented as the mean ± standard deviation.

Table III. Functional outcomes in each group.

	Functional outcome (%)				
Surgery group	Excellent	Good	Fair	Poor	P-value
Open surgery (n=72)	60 (83.34)	6 (8.33)	5 (6.94)	1 (1.40)	0.848
Arthroscopic surgery (n=41)	33 (80.48)	5 (12.20)	3 (7.32)	0 (0.00)	

administered. Each tablet contained 5 mg of oxycodone hydrochloride and 325 mg of acetaminophen.

Outcome measurements. GMC has special characteristics and methods of outcome evaluations although it can also be considered as one kind of the hip joint disease. The function evaluation indicators of GMC include crouch with knees close together, cross-legged sitting functions, gait, pain, and discomfort, etc. Thus single hip range of motion will not fully reflect function improvement of GMC. The criteria applied to evaluate the GMC function and effect during the follow-up period in this study were according to previous literatures (8,9). The validity of the results was described in terms of four grades: Excellent (100-85 points), good (84-70 points), fair (69-60 points) and poor (<60 points). The evaluation indicators were as follows: A full score of 10 points was recorded for normal crouching with both knees close together, significantly improved walking gait, no hip snapping, no hip pain or discomfort, normal blood vessel and nerve functions, and normal hip adduction activities; a full score of 8 points was recorded for normal hip flexion and cross-legged sitting functions, negative Ober's sign, normal crossed-leg test, no haematoma and effusion, and wound healing after first treatment.

Statistical analysis. Statistical analysis was performed with SPSS software (version 20.0; SPSS, Inc., Chicago, IL, USA). Enumeration data were analysed by χ^2 tests, Measurement data were tested for normality with the Kolmogorov-Smirnov test and the statistical analysis was performed with the two-tailed Student's t-test. $P<0.05$ was considered to indicate a statistically significant difference.

Results

The mean follow-up time was 2.23 years (range, 1-5 years) for the open surgery group and 2.10 years (range, 1-5 years) for the arthroscopic surgery group. There was no significant difference in the follow-up time between the two groups. The surgical duration (bilateral) was 30 to 70 min (mean: 42.89 min) in the open surgery group and 50 to 80 min in the arthroscopic surgery group (mean: 62.68 min). The sizes of incisions (bilateral) were 8 to 13 cm (mean: 10.23 cm) in the open surgery group, and 3 to 4 cm (mean: 3.07 cm) in the arthroscopic surgery group. The mean blood loss (bilateral) was 214.51 ml for the open surgery group and 76.83 ml for the arthroscopic surgery group. The hospital stay was 5 to 17 days (mean: 9.30 days) for the open surgery group and 5 to 8 days (mean: 6.12 days) for the arthroscopic surgery group. The mean postoperative analgesic dose (based on oxycodone) was 6.83 mg for the open surgery group and 3.29 mg for the arthroscopic surgery group. The two groups showed significant differences in terms of surgical duration, incision size, blood loss (intraoperative plus postoperative), hospital stay and postoperative analgesic dose ($P<0.05$; Table II).

The open surgery group had 60 patients rated excellent, 6 patients rated good, 5 patients rated acceptable and 1 patient rated poor. The arthroscopic surgery group had 33 patients rated excellent, 5 patients rated good, 3 patients rated acceptable and no patient rated poor. Excellent and good rates accounted for 91.67% in the open surgery group, and 92.68% in the arthroscopic surgery group, respectively. There was no significant difference in the ranking of functions and effects between the two groups ($\chi^2=0.037$, $P=0.848$; Table III).

In the open surgery group, 6 cases experienced wound haematoma, while 4 cases showed delayed wound healing and wound rupture. No patients in this group had residual hip snapping or vessel and nerve injuries after surgery. One patient in this group presented a 'swaying gait' after surgery that improved after 3 months of functional exercise. In the arthroscopic surgery group, we found no wound haematoma, delayed wound healing and rupture, wound infection, hip muscle weakness, 'swaying' gait, postoperative residual snapping of the hip, or vascular and nerve injuries.

Discussion

GMC often occurs in patients who received intramuscular injections as infants and pre-schoolers (3). Epidemiological investigations in China show that the incidence of GMC ranges from 0.7 to 10.1% (1,2,4,5). The pathogenesis of GMC is not completely understood. Numerous studies have suggested that repeated intramuscular injections are the primary pathogenic factor for GMC and that chemical stimulation via drug injection plays a greater role than simple mechanical stimulation (1,3,10-12). Patients with GMC walk with a toe-out gait, present impairments when crouching with the knees close together, and have limitations in the abduction and internal rotation of the hip. The surgical treatment of GMC aims to improve lower limb function and gait and to improve patients' social function and appearance (13).

Surgical treatments for GMC include open surgery and arthroscopic surgery. These two types of surgeries have specific advantages and disadvantages and different scopes of application. The advantages of open GMC release are as follows (14-21): it supports clear exposure; it allows for complete release that includes the joint capsule and the biceps femoris tendon in cases of severe GMC [grade III, according to the classification criteria of He *et al* (1)], and it exposes and protects the sciatic nerve. The disadvantages are that it results in substantial surgical trauma; it is difficult to achieve complete haemostasis after the scar tissue is cut off, which results in considerable postoperative wound drainage and encourages deep wound haematomas and haematoma-induced delayed wound healing and wound infection; and it requires a relatively long incision, which affects the patients' appearance and may particularly affect young women. The advantages of arthroscopic GMC release are that allows the surgeon to clearly identify scar tissue under the arthroscope and accurately release the contractile bands scattered between muscle bundles without cutting off normal muscle; it allows for simultaneous haemostasis, including that of minor bleeding points during release, which significantly reduces postoperative wound drainage and the probability of wound haematoma; and it requires a small incision, which meets the patients' aesthetic requirements, particularly those of young women. The disadvantages are that the procedure for severe GMC is difficult; it is difficult to effectively expose the gluteus minimus, piriformis, joint capsule and sciatic nerve; for contractures deeper than the gluteus medius, it is difficult to achieve extensive and thorough release while ensuring the safety of the sciatic nerve; for GMC cases with the same degree of contracture, the duration of arthroscopic surgery performed by beginners is longer than that of open surgery; and it has a relatively low efficiency for release and is unsuitable for the release of GMCs in large areas (22,23).

Generally, open surgery is suitable for releasing various degrees and types of GMC, and it is particularly suitable for severe (e.g., grade III) GMC (1,7,14,19,24). Arthroscopic surgery is suitable for mild GMC (e.g., grade II) with a relatively limited area. At present, most GMC patients seeking treatment in China are adults with relatively mild contractures. The technical characteristics of arthroscopic GMC release indicate that this surgical approach is more suitable than open surgery for such patients.

In this study, the arthroscopic surgery group had a slightly longer surgical duration than the open surgery group. This is because the efficiency of release with the radiofrequency device under arthroscopy is lower than the efficiency of an electrotome or blade during open surgery. Despite its lower release efficiency, arthroscopic surgery achieves more accurate release and more careful haemostasis. The incision length in the arthroscopic surgery group was markedly shorter than that of the open surgery group. Moreover, it has been reported that skin scarring caused by surgical incision is prominent in patients with GMC and seriously affects their appearance. He *et al* reported that of 187 patients who underwent open surgery, 62 developed a severely bulging scar that was raised as high as 0.8 cm above the surrounding skin (1). In GMC cases, the scar tissue bleeds more than normal muscle tissue; additionally, the broken end of the scar tissue retracts after release, which increases the difficulty of obtaining haemostasis during open surgery. In contrast, arthroscopic surgery can clearly identify the bleeding points and quickly stop the bleeding, resulting in markedly less postoperative drainage in the arthroscopic surgery group than in the open surgery group. The analgesic dose can indirectly reflect a patient's degree of surgical trauma. In this study, the analgesic dose was significantly lower in the arthroscopic surgery group compared with the open surgery group, which also indirectly indicates that the arthroscopic surgery was less invasive. There was a significant difference in the duration of hospital stay between the arthroscopic and open surgery groups, mainly because the patients in arthroscopic surgery group began functional exercises earlier and required less time for wound observation and functional exercise guidance.

The comparison of postoperative functions and effects revealed no significant differences between the arthroscopic and open surgery groups, indicating that the two surgeries achieved equivalent release effects. However, 6 cases in the open surgery group developed wound haematoma. Of these, 2 cases improved after conservative treatment (puncture and drainage), and 4 cases showed delayed wound healing and wound rupture and healed after debridement. Among the 4 cases of wound rupture, 1 case developed infection. Bacterial culture result revealed the presence of Escherichia coli and the case was cured after treatment with appropriate antibiotics. In the arthroscopic surgery group, rigorous haemostasis resulted in no wound haematoma, delayed wound healing, wound rupture, or wound infection.

The follow-up results reported above show that arthroscopic GMC release resulted in less trauma, less invasion and fewer surgical complications while achieving a release effect consistent with that of open surgery.

Because at present, untreated GMC patients are primarily adults, the GMC patients who were followed in this study were all adults. Based on previous clinical experience in our department, juveniles might have better flexibility, and postoperative functional recovery in GMC is generally faster and better for juveniles than for adults. Zhao *et al* found that age was an important factor that influenced the results of both non-surgical and surgical management. Patients in the juvenile group had better results than the adolescent group for both treatments (6). A simple follow-up study of adults could exclude the effect of age-related physical factors on functional recovery and be more conducive to assessing the effect differences in treatment methods (24).

The study has several limitations. Firstly, the retrospective non-randomized design has all of the inherent limitations of such study. Secondly, the decision in treatment modality is made at the discretion of the chief operating surgeon which may produce potential bias. Thirdly, the findings showed in this study are from a single-center hospital, which may reflect regional and institutional bias.

In conclusion, existing untreated patients with GMC mostly have low-severity (e.g., grade II) contractures of limited area are more suitable for arthroscopic GMC release due to its advantages of limited surgical trauma, a small incision, lower blood loss and fewer surgical complications. Preoperative accurate assessment of the depth, range, and distribution of scars of GMC by a combined clinical and radiographic examination is the future direction because it can accurately guide the release of GMC during surgery and reduce unnecessary injuries.

Acknowledgements

Not applicable.

Funding

No funding was received.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

TZ and XH conceived the study. TZ performed the literature search and wrote the manuscript. SX analyzed and interpreted the data. HL and FZ collected and assembled the data. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study was approved by the ethics committee of the Second Affiliated Hospital of Xi'an Jiaotong University and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from each patient prior to the surgical procedures.

Consent for publication

The subjects gave written informed consent for the publication of their data and accompanying images.

Competing interests

The authors declare that they have no competing interests.

References

1. He X, Li H and Wang D: Classification and management of the gluteal muscles contracture. Chinese J Orthop 23: 96-99, 2003.
2. Wang B, He X, Wu Y, Fang D and Liu J: The prospective study and factors analysis for gluteus contracture. China J Orthop Traumatol 3: 157-158, 2003 (In Chinese).
3. Fernandez de Valderrama JA and Esteve de Miguel R: Fibrosis of the gluteus maximus: A cause of limited flexion and adduction of the hip in children. Clin Orthop Relat Res: 67-78, 1981.
4. Wang Y, Shi J, Chen W and Gao Y: The epidemiological investigation of gluteal muscle contracture of male students in the physical examination for navy pilot recruitment. Chin J Aerospace Med 26: 203-207, 2015.
5. Hu X, Tan X, Zheng M, Kuang R, Liang J, Wei W, Wang H, Zeng B and Wang G: Epidemiological survey of gluteal muscle contracture of primary and secondary students in Rongchang county. Chongq Med 44: 368-371, 2015 (In Chinese).
6. Zhao CG, He XJ, Lu B, Li HP, Wang D and Zhu ZZ: Classification of gluteal muscle contracture in children and outcome of different treatments. BMC Musculoskelet Disord 10: 34, 2009.
7. Wang D, Liu Z, He X, Li H and Xu S: Operative treatment of the serious gluteus contracture. Orthoped J China 17: 1189-1190, 2009 (In Chinese).
8. Liu YJ, Xue J, Zhou M, Wang ZG, Li ZL, Cai X, Wei M, Wang Y and Zhu JL: Arthroscope monitored solution of adult intramuscular injection associated gluteal muscle contracture by radiofrequency. Zhonghua Wai Ke Za Zhi 46: 970-972, 2008.
9. Fu D, Yang S, Xiao B, Wang H and Meng C: Comparison of endoscopic surgery and open surgery for gluteal muscle contracture. J Pediatr Orthop 31: e38-e43, 2011.
10. Zhao CG, He XJ, Lu B, Li HP and Kang AJ: Increased expression of collagens, transforming growth factor-beta1, and -beta3 in gluteal muscle contracture. BMC Musculoskelet Disord 11: 15, 2010.
11. Zhao CG, Qin J, He XJ, Guan YC, Jia Y and Lei W: Sphingosine-1-phosphate is a possible fibrogenic factor in gluteal muscle fibrosis. Physiol Res 62: 691-699, 2013.
12. Zhang X, Ma Y, You T, Tian X, Zhang H, Zhu Q and Zhang W: Roles of TGF-β/Smad signaling pathway in pathogenesis and development of gluteal muscle contracture. Connect Tissue Res 56: 9-17, 2015.
13. Rai S, Meng C, Wang X, Chaudhary N, Jin S, Yang S and Wang H: Gluteal muscle contracture: Diagnosis and management options. SICOT J 3: 1, 2017.
14. Liu G, Yang S, Du J, Zheng Q, Shao Z and Yang C: Treatment of severe gluteal muscle contracture in children. J Huazhong Univ Sci Technolog Med Sci 28: 171-173, 2008.
15. Al Bayati MA and Kraidy BK: Gluteal muscle fibrosis with abduction contracture of the hip. Int Orthop 40: 447-451, 2016.
16. Xu J, Geng X, Muhammad H, Wang X, Huang JZ, Zhang C and Ma X: Comparison of the incisions for the open surgical treatment of gluteal muscle contracture. J Pediatr Orthop B 23: 435-440, 2014.
17. Ye B, Zhou P, Xia Y, Chen Y, Yu J and Xu S: New minimally invasive option for the treatment of gluteal muscle contracture. Orthopedics 35: e1692-e1698, 2012.
18. Tang X, Liu L and Peng M: Diagnosis and treatment of gluteal muscle contracture associated with unequal leg length caused by pelvis obliquity. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 20: 835-837, 2006 (In Chinese).
19. Chen HS and Yang XL: Insertion of gluteus maximus tendo-chilles lengthening with Z-shaped for the treatment of severe gluteal muscle contracture. Zhongguo Gu Shang 28: 524-526, 2015 (In Chinese).
20. Chen X, Tang X, Jiang X, Wang D, Peng M and Liu L: Diagnosis and treatment of unilateral gluteal muscle contracture. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 25: 530-532, 2011 (In Chinese).
21. Xiao Y, Tang ZH, Zhang SR, Zou GY, Xiao RC, Liu RD and Hu JZ: The first exploration of a minimally invasive lysis subcutaneouly for the treatment of gluteal muscle contracture based on relatively safe region around standard injection point of gluteal muscle. Zhongguo Gu Shang 24: 514-516, 2011 (In Chinese).
22. Liu YJ, Wang Y, Xue J, Lui PP and Chan KM: Arthroscopic gluteal muscle contracture release with radiofrequency energy. Clin Orthop Relat Res 467: 799-804, 2009.
23. Zhang X, Jiang X, He F, Liang Z, You T, Jin D and Zhang W: Arthroscopic revision release of gluteal muscle contracture after failed primary open surgery. Int Orthop 41: 1521-1526, 2017.
24. Liu GH, Cao FQ, Yang SH and Zhu JF: Factors influencing the treatment of severe gluteal muscle contracture in children. J Pediatr Orthop B 20: 67-69, 2011.