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ORIGINAL ARTICLE

Balloon kyphoplasty and percutaneous fixation of lumbar fractures in pediatric patients

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Abstract
Purpose Type A fractures of the spine requiring operative stabilization are rare injuries in the pediatric population. Current reports have demonstrated the safety of the combination of balloon kyphoplasty and minimal invasive management of thoraco-lumbar fractures in adults. There is no information about the efficacy of this approach in managing pediatric vertebral fractures.
Methods The aim of the present study was to report the outcome of a small series of children with A fractures of the lumbar spine treated with the combination of the abovementioned techniques.
Results Three male patients without neurological deficits aged 11, 12 and 14 years were treated with fractures located at L1, L1/L2 and L2/L3, respectively. In total, six kyphoplasties were performed (monolateral in 4 vertebrae, bilateral in one vertebra). Neither cases of cement leakage nor intra- or postoperative complications were noted. Minimally invasive kyphoplasty and stabilization led to a significant improvement of the sagittal index of all five treated vertebrae which could be maintained at follow-up (14, 19 and 20 months postoperatively).
Conclusion This study is the first one to present an excellent outcome of children with type A fractures treated with a combination of balloon kyphoplasty and percutaneous stabilization.

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Introduction

With a reported incidence of 0.6 %, fractures of the spine are exceedingly rare injuries encountered in the pediatric population [1]. In children and adults, the majority of spinal fractures occur at the thoraco-lumbar junction [2].

According to the AO Magerl classification, fractures of the spinal column can be classified as type A, B and C fractures [3]. There is no doubt that both, B and C fractures, necessitate operative intervention. However, the majority of pediatric patients with thoraco-lumbar and lumbar type A fractures without neurological deficits can be treated conservatively with bed rest or immobilization using cast or orthesis [4–7]. Nevertheless, recommendations for the treatment of type A fractures with signs of instability, anterior body compression greater than 50 %, spinal canal compromise greater than 50 % or kyphosis of more than 15° include operative stabilization [8].

In adults, various surgical methods of reconstruction and stabilization have been described including the anterior, posterior or combined approaches [9–13]. Percutaneous stabilization of spinal fractures is gaining increasing popularity [14–16]. Advantages of this approach include minimization of blood loss, reduced time for operative intervention, less postoperative pain, limited risk of infection and shortened stay in hospital [14, 17]. Recently, the percutaneous injection of various bone cements has been introduced to support the anterior column. This method was further refined by the introduction of balloon kyphoplasty in which a cavity in the vertebral body is created using an inflatable balloon prior to cement augmentation

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[18]. Some current reports have now demonstrated the safety of the combination of balloon kyphoplasty and minimal invasive management of thoraco-lumbar fractures in adults [17, 19, 20].

However, the literature is void of information about balloon kyphoplasty and percutaneous stabilization of thoraco-lumbar and lumbar fractures in children. The aim of the present study was to report the outcome of a small series of children sustaining type A fractures of the lumbar spine treated with the combination of the abovementioned techniques.

Patients and methods

During a 7-month period, three patients with 5 type A vertebral fractures of the thoraco-lumbar region were treated with minimal invasive kyphoplasty using calcium phosphate and percutaneous stabilization. These patients were retrospectively reviewed. All patients were male and aged 11, 12 and 14 years. The treated fractures were located at L1, L1/L2 and L2/L3, respectively. All fractures were classified according to Magerl [3]. None of the patients showed neurological deficits.

The patients underwent standard X-rays in two planes and a CT scan prior to surgical treatment. Standard X-rays in two planes were performed postoperatively. One patient additionally underwent a CT scan after implant removal. Implant removal was performed 6, 8 and 9 months postoperatively.

Different spinal parameters (sagittal index, modified Cobb angle of Daniaux—the angle in sagittal view between the caudal endplate of the lowest injured vertebra and the cranial endplate of the first non-injured adjacent cranial vertebra—and segmental scoliosis angle—the angle in AP view between adjacent endplates) were measured [21, 22] on preoperative images and compared to the values assessed immediately postoperatively and at follow-up. Follow-up values were evaluated 14, 19 and 20 months after stabilization.

In addition, data about the operative time, blood loss, the amount of calcium phosphate injected and complications were collected.

For comparing the sagittal index, a one-way ANOVA with Scheffe test was used. Data are presented as mean ± SE. Statistical significance was set at a p value <0.05.

Surgical procedure

The surgical procedure was performed with the patients in prone position on a radiolucent carbon operating table. Despite placement of the patient in hyperlordosis, no correction of the fractured vertebrae was seen. No additional special maneuvers were performed. The head was gently fixed in neutral position to avoid rotation and flexion/extension. The upper extremities were in before-head crossed-arm position. Two image intensifiers for AP and lateral views were used. The intensifier for lateral views was covered with sterile drapery and mounted in a fixed position. The intensifier for the a.p. views was covered and kept mobile to change the position during surgery to allow save screw placement. At first, balloon kyphoplasty (Kyphon, Medtronic, Minneapolis, Minnesota, USA) and injection of calcium phosphate (Kyphos, Medtronic, Minneapolis, Minnesota, USA) were performed. To attribute the strong pediatric bone, the kyphoplasty was realized very carefully raising the pressure stepwise (50 PSI) and pausing until the pressure declined to a stable value. To monitor the correct erection of the fractured vertebra, repeated X-rays were taken. All X-rays were taken by an experienced radiological technologist.

Following kyphoplasty, dorsal percutaneous instrumentation of the adjacent segments using the Medtronic Longitude system (Medtronic, Minneapolis, Minnesota, USA) was realized. The fascia was carefully closed to avoid subcutaneous hematoma.

Postoperatively, the patients had bed rest for 24 h to facilitate hardening of the cement followed by mobilization with full weight bearing and without brace. Sports activities were prohibited for 6 weeks and contact sports for 3 months.

Results

The demographic data of the patients are presented in Table 1. The injury mechanisms were a fall from a height of 3 m, a bicycle and a skiing accident, respectively. Patient 1 additionally presented with a distal forearm fracture and Patient 3 sustained A1 fractures of T7 and T8 which were treated conservatively.

Patients 1 and 2 were initially managed conservatively with physical therapy and bracing. However, while the posttraumatic thoraco-lumbar kyphosis did not change during conservative treatment, there was an increase of scoliosis (from 0° to 10° in Patient 1 and 5° to 20° in Patient 2 combined with persisting pain) necessitating surgical intervention on the 8th posttraumatic day. Patient 3 was instantly scheduled for kyphoplasty and percutaneous fixation because of incomplete burst fracture with stenosis of the spinal canal.

In total, six kyphoplasties were performed (monolateral in the 4 vertebrae of Patients 1 and 2 due to the posttraumatic scoliosis, bilateral in the vertebra of Patient 3). The average volume of calcium phosphate injected was 5.5 ml (range 4.4–6.4 ml). There were no cases of cement

Table 1 Summary of the demographic data of three children treated with percutaneous kyphoplasty and dorsal stabilization

Patient	Age	Sex	Mechanism	Level	Type	Instrumentation from–to
1	11a	M	Fall from >3 m	L2	A 1.2.2	L1–L4
				L3	A 3.1.2	
2	12a	M	Bicycle	L1	A 3.1.1	T12–L3
				L2	A 1.2.1	
3	14a	M	Skiing	L1	A 3.1.1	T12–L2

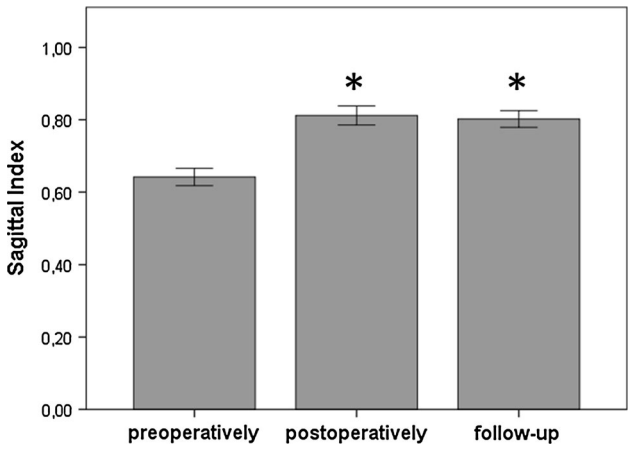

Fig. 1 Comparison of the preoperative, postoperative and follow-up (14, 19 and 20 months postoperatively) sagittal index of five vertebrae treated with kyphoplasty and percutaneous stabilization. *$p < 0.05$ vs. preoperative values

leakage. The operative time was 140, 100 and 135 min, respectively. Hospital stay was 6, 10 and 5 days. The dose of radiation was 2,793, 316 and 1,520 cGy cm^2. No intra- or postoperative complications were recorded. Pain improved from preoperative VAS 3, 4 and 3 to VAS 2, 2 and 2 on the first postoperative day and VAS 1, 1 and 0 on the third postoperative day. All patients were fully mobilized at time of discharge and were sufficiently treated with NSAIDs on demand. Implant removal was performed 6, 8 and 9 months postoperatively.

Figures 1, 2 demonstrate that minimally invasive kyphoplasty and stabilization led to a significant improvement of the sagittal index of all five treated vertebrae which could be maintained at follow-up (14, 19 and 20 months postoperatively). The improvement of both the Cobb and scoliosis angle assessed pre-, postoperatively and at follow-up is shown in Table 2.

All three patients are fully reintegrated into normal life activity and can perform sports on a preoperative level.

Discussion

The present study provides the first step to demonstrate the safety and efficacy of minimal invasive kyphoplasty combined with percutaneous fixation in children. There is no doubt that type B and C fractures necessitate operative stabilization [23, 24]. However, it has been shown that almost three quarters of pediatric thoraco-lumbar fractures are type A compression fractures [25]. The majority of type A fractures can be treated conservatively.

For higher grade type A fractures, many surgical techniques including the anterior, posterior or combined approaches have been described but none has proved its superiority over others [26]. The main disadvantages of these methods are directly related to the morbidity of the surgical approach. To reduce the iatrogenic lesions including muscle denervation, ischemia and infection [27], new approaches have been developed.

Initially reported for degenerative diseases [28], the percutaneous pedicle screwing technique is now gaining increasing popularity for the treatment of thoraco-lumbar spinal fractures [16]. However, initial results were disappointing with failure rates of fixation as high as 50 % [28]. Balloon kyphoplasty was introduced as a promising new technique. Gioia et al. [29] have treated six patients presenting with type A fractures with a mean age of 38 years using balloon kyphoplasty and injection of calcium phosphate without further stabilization. The patients were postoperatively treated with a brace in an erect position for 60 days. Nevertheless, the initial improvement of the kyphosis angle could not be maintained after 45 days. These results suggest that either method is not sufficient for treatment of thoraco-lumbar compression fractures. The active reduction achieved by balloon kyphoplasty can be protected by internal fixation of the affected spinal segments.

With the combination of kyphoplasty and percutaneous stabilization these unacceptably high failure rates can be avoided. Recently, the safety and efficacy of the combination of percutaneous stabilization plus balloon kyphoplasty have been demonstrated in 41 adult patients sustaining thoraco-lumbar fractures [17]. In addition, a group of patients with A3 fractures between T9 and L2 treated with kyphoplasty and pedicle screw instrumentation yielding favorable outcome at the end of a follow-up period of mean 26 months has been reported [30]. These results suggest that this percutaneous combination provides a promising method of treating type A fractures in adults without neurologic deficits.

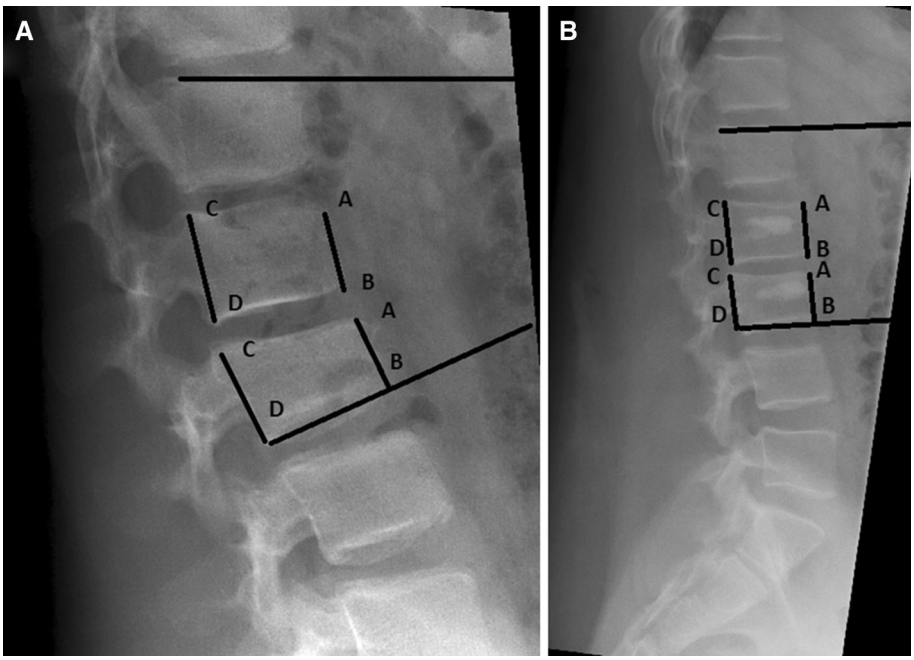

Fig. 2 Preoperative radiographs of Patient 1 showing a sagittal index (*AB*:*CD*) of 0.63 for L2 and 0.66 for L3 and a modified Cobb angle of −4° (**a**). Radiographs of Patient 1 at follow-up (19 months postoperatively) with a sagittal index (*AB*:*CD*) of 0.77 for L2 and 0.79 for L3 and a modified Cobb angle of +4° (**b**)

Table 2 Comparison of the Cobb angle and scoliosis angle assessed pre-, postoperatively and at follow-up (14, 19 and 20 months following stabilization)

	Cobb angle			Scoliosis angle		
	Preop	Postop	f/u	Preop	Postop	f/u
Patient 1	−4°	+10°	+4°	10°	0°	0°
Patient 2	−10°	+20°	+2°	20°	2°	5°
Patient 3	−3°	+8°	+3°	5°	1°	0°

We are now able to extend these findings by reporting the excellent outcome of three children who were treated using the abovementioned combined approach. Immediately postoperatively, the sagittal index was significantly improved and maintained at follow-up 14, 19 and 20 months after the operative stabilization (Fig. 1). The postoperative increase of the Cobb angle which again decreased following implant removal seen in Patient 2 (Table 2) might be explained by an overcorrection due to the stabilization.

In children and adolescents, possible long-term sequelae of vertebral fractures due to misalignment and hyperkyphosis might occur [31]. While a certain remodeling potential of compression fractures has been described in the sagittal plane in young children there is less potential for remodeling in the frontal plane [32, 33]. Comparing a group of operatively versus conservatively treated patients with type A3 fractures, it has been shown that both local and regional kyphotic deformities were significantly less in the operatively treated group. In addition, functional outcome scores showed significantly better results in the operative group [34]. A multicenter study demonstrated that operative management of type A fractures with hyperkyphosis of the thoraco-lumbar region can prevent persisting hyperkyphosis, reduces pain and leads to faster reintegration compared to conservative treatment [35]. Remodeling of the spinal vertebra after type A fracture has been described. Remodeling showed to be best in patients under ten years of age. In addition, it is desirable to facilitate a short hospital stay combined with an early reintegration into social life. The combination of percutaneous fixation and balloon kyphoplasty using calcium phosphate seems to be an adequate method to reach these goals. Operative time and length of hospital stay are short and there is less iatrogenic trauma compared to conventional approaches. Moreover, it is also possible to perform implant removal using the same minimally invasive approach. Implant removal is uniformly recommended in young patients to preserve mobility of the adjacent levels [30].

The percutaneous stabilization is not free of risks. It can cause nerve injuries and the screws might be misplaced causing violation of the facet joints. Therefore, to protect the facet joints, the insertion point of the pedicle screws should be chosen as lateral and caudal as possible in relation to the pedicle. In addition, we recommend usage of two image intensifiers for frontal and lateral views. The introduction of cement can also lead to leakage into the spinal cord which has been reported in up to 25 % of the patients treated [36]. The use of balloon kyphoplasty prior to injection can prevent the cement from entering the spinal

cord and therefore minimizes the risk of mechanical compression and exothermic reactions involving nerval structures [36].

Limitations of the present study include the low number of patients and the short follow-up. However, the rarity of pediatric thoraco-lumbar fractures necessitating operative stabilization has to be taken into account. Only 0.6 % of all pediatric fractures are fractures of the spinal column and only 13 % of these necessitate operative intervention [1, 25]. The results of the present study are promising and suggest that the combination of balloon kyphoplasty and percutaneous stabilization might be a useful approach for selected cases of pediatric type A fractures of the thoraco-lumbar spine. Further clinical studies, however, have to be done to confirm the efficacy of this approach and to demonstrate its long-term safety.

In conclusion, we were able to demonstrate a significant improvement and maintenance of the sagittal index as well as spinal balance comparing pre-, postoperative and follow-up values in children with lumbar type A compression fractures. This study is the first one to present the feasibility and an excellent outcome of the combination of balloon kyphoplasty and percutaneous stabilization for treatment of children sustaining type A fractures of the spinal column. However, further long-term examinations of our patients are mandatory to rule out repercussions on spinal growth. In addition, performance of long-term MRI would address the question of osteointegration of the calcium phosphate as well as potential iatrogenic damage to the facet joints. The majority of pediatric thoraco-lumbar type A fractures still can be successfully treated conservatively.

Conflict of interest None.

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