Woodward Procedure Improves Shoulder Function in Sprengel Deformity

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Background: Sprengel deformity is a congenital failure of descent of the scapula. Limited shoulder abduction and cosmetic appearance are the major concerns. Although the Woodward procedure reportedly affords satisfactory correction, the long-term functional outcome postoperatively has not been addressed.

Methods: Eight patients (9 shoulders) who underwent the Woodward procedure for Sprengel deformity were evaluated. The cosmetic appearance and functional results of the shoulders were evaluated using the Cavendish grading system and functional Constant scoring. Grading of the cosmetic appearance, range of motion of the shoulder, and radiographs were obtained for interpretation.

Results: After a mean follow-up of 113 ± 29 months, the cosmetic appearance had improved. The Cavendish cosmetic grade improved significantly ($p = 0.000$). The superior displacement ratio decreased from 0.5 ± 0.1 to 0.2 ± 0.1 ($p = 0.004$). The height-to-width ratio of the affected scapula increased from 1.3 ± 0.2 (range 1.1 to 1.7) to 1.6 ± 0.2 (range 1.4 to 2.0) ($p = 0.001$). The abduction of the shoulder improved from 122 ± 14 (range 100 to 140) degrees to 157 ± 20 (range 125 to 180) degrees ($p = 0.008$). The average abduction power of the involved shoulders was 21.8 ± 3.2 lbs, which was not significantly different from the uninvolved shoulders 23.1 ± 2.5 lb ($p = 0.525$). The average Constant score for the operated shoulders was 91.7 ± 4.2 (range 82 to 96) points.

Conclusion: The Woodward procedure offers substantial improvement of shoulder function and cosmetic appearance for patients.

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Key words: sprengel deformity, Woodward procedure

Patients with a Sprengel deformity have a non-descending and derotated scapula during development in utero. The pathogenesis is unclear. The cosmetic appearance and limitation of shoulder abduction are the major concerns. Various procedures,[1-3] including the Putti and Green procedures, have been employed to correct the deformities. The Woodward procedure is useful for moving the origins of the trapezius and rhomboids to the thoracic spine. While this procedure is beneficial and has few complications,[4] few studies have been conducted to evaluate the functional outcome after long-term fol-

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low-up. The purpose of this study was to retrospectively evaluate the cosmetic appearance, function, and computed tomographic (CT) images of the shoulder after 10 years of follow-up in a group of patients with Sprendal deformity who had a Woodward procedure. We suggest that the Woodward procedure improves the cosmetic appearance and functional results postoperatively.

METHODS

Between May 1998 and January 2004, Woodward procedures were performed on 8 patients, (3 boys and 5 girls) with 9 involved shoulders (7 left shoulders and 2 right shoulders). The age of the patients at the time of the operation was 6.3 ± 3.1 years (range, 4 to 11 years). The preoperative cosmetic appearance, abduction function of the shoulder, radiographs and associated deformities were documented for interpretation. The cosmetic appearance was evaluated using the Cavendish grading system (1. very mild, 2. mild, 3. moderate, 4. severe deformity) preoperatively and postoperatively.[5]

Shoulder structures were evaluated by CT (7 shoulders) and magnetic resonance imaging (MRI) (2 shoulders) preoperatively. The radiographic assessments included measurement of the superior displacement ratio and height-to-width ratio of the scapula in the posterior scapular view from preoperative images such as chest radiographs or CT. The superior displacement ratio was measured by drawing two reference lines. Line 1 was drawn from the center of the glenoid cavity of the affected shoulder perpendicular to the vertebral axis line, and line 2 was drawn from the normal shoulder. The superior displacement ratio was formed by the distance between these two lines as a fraction of the scapular height on the normal side. This ratio is not measured in bilateral cases, as there is no normal side to use as a reference (Fig. 1). To evaluate the height-to-width ratio, the height of the scapula was measured from the superior angle to the inferior angle parallel to the glenoid, and the width was measured from the cavity of the glenoid to the most medial portion of the vertebral border perpendicular to the glenoid. To measure scapular lowering after surgery, the inferomedial angle of the scapula was used as the reference point for evaluation.[6] Associated spinal anomalies, scoliosis and hemivertebrae were documented.

The Woodward procedure included detachment of the origins of the trapezius and rhomboid muscles from the spinous process and caudal displacement of the elevated scapula after excision of any omovertebral bone or fibrous connection on the scapula. The attached muscles from the superior and medial borders of the scapula were reflected extraperiosteally. A scapuloplasty was performed with excision of the superiomedial border of the scapula, according to preoperative 3D-reconstructed CT or MRI planning, to reshape the contour of the deformed scapula (Fig.

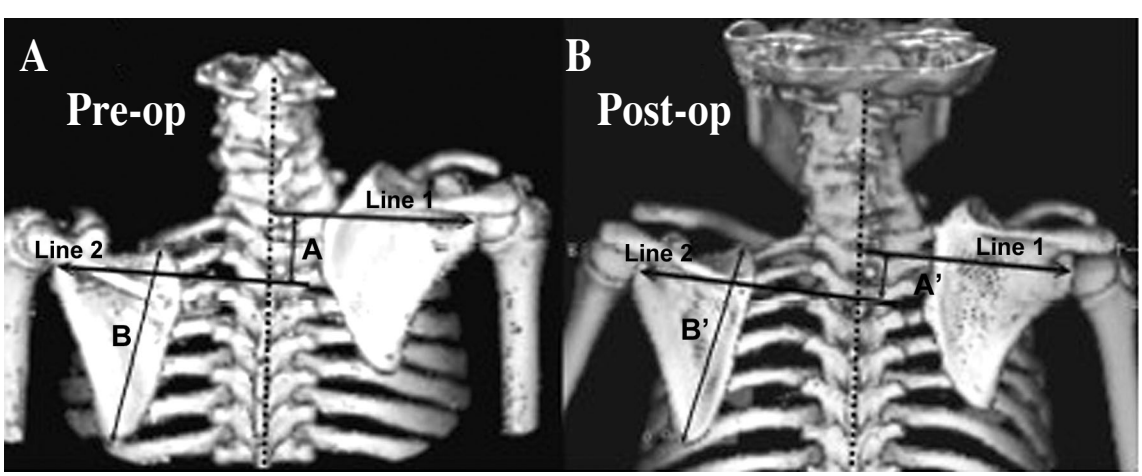

Fig. 1 Measurement of the superior displacement ratio before (A/B) (A) and after (A'/B') (B) the Woodward procedures. Line 1 is drawn from the center of the glenoid cavity of the affected shoulder perpendicular to the vertebral axis line and line 2 is drawn from the normal shoulder. The superior displacement A/B ratio is formed by the distance between these two lines (A) as a fraction of the scapular height on the normal side (B).

2). The scapula and detached muscles were relocated with heavy sutures. No clavicle osteotomy or external fixation was performed in any patient.

Patients received Velpeau sling protection for one week, followed by progressive rehabilitation of the operated shoulder. Patients were followed up at 1 month, 3 months and annually after surgery. The cosmetic appearance, abduction of the shoulder and Constant and Murley functional scores with subjective symptoms, objective findings and muscle power strength were recorded at the follow-ups. A handheld dynamometer (Hoggan Health Inc, West Jordan, Utah, U.S.A.) was used for quantitative measurement of the abduction muscle strength.

Statistical analysis was performed with SPSS version 15.0 (SPSS, Inc, Chicago, IL, U.S.A.). The cosmetic grades and degree of abduction and muscle strength were evaluated with the use of paired t-tests. Spearman's correlation analysis was used for correlation between age at treatment and functional outcome. A p value < 0.05 was considered statistically significant.

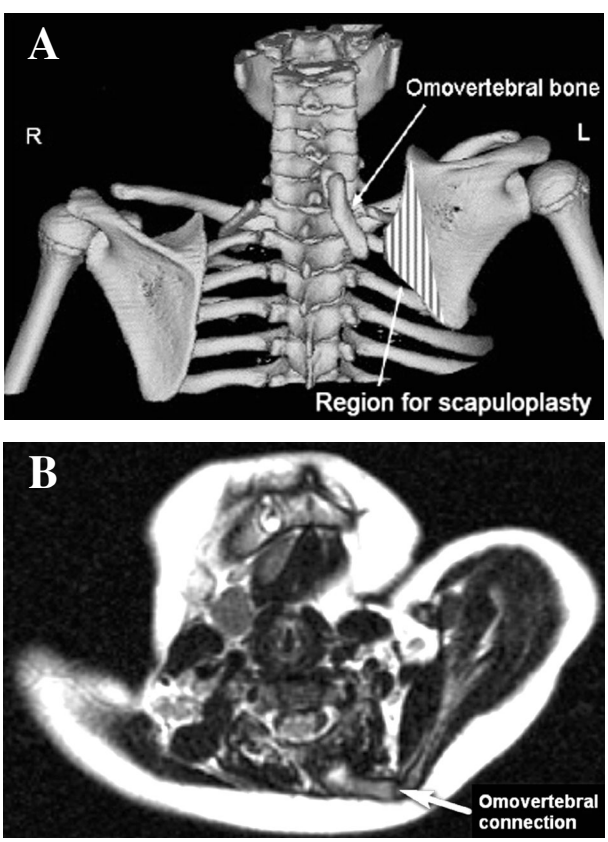

Fig. 2 Preoperative planning with 3D reconstructed CT scanning (A) or MRI study (B). The omovertebral bone and the shape of the affected scapula are visible. The region of scapuloplasty is drawn in shadow by Ulead photoimpact (version 12, Taipei, Taiwan) software for putative correction of the height-to-width ratio.

RESULTS

Pertinent data from the patients are summarized in Table 1. Two patients had scoliosis, 2 showed hemivertebrae, 2 displayed bifurcation of the cervical spine, 1 had congenital torticollis, and 1 had hydrocephalus and polydactyly. Seven of the patients had an omovertebral bony connection; the other patient (Case 4) had a fibro-cartilage connection between the cervical spine and scapula. The average hospitalization was 6.1 ± 1.7 days (range 4 to 9 days). At the latest follow-up at 113 ± 29 (78 to 140) months, the Cavendish cosmetic grade had improved significantly (p = 0.000). The superior displacement ratio improved from 0.5 ± 0.1 to 0.2 ± 0.1 (p = 0.004) and the scapula lowered by 2.2 ± 1.2 cm (range 0.9 to 4.8 cm) (Fig. 3). Compared with the contralateral side, the pre-operative height to width ratio of the affected scapula had decreased by 17.6%. This ratio was significantly (p = 0.001) corrected from 1.3 ± 0.2 (range 1.1 to 1.7) to 1.6 ± 0.2 (range 1.4 to 2.0) postoperatively, and was comparable to the normal side (1.6 ± 0.2, p = 0.821). The abduction of the shoulder was improved from 122 ± 14 degrees (range 100 to 140 degrees) to 157 ± 20 degrees (range 125 to 180 degrees) (p = 0.008). The average abduction muscle power of the involved shoulder was 21.8 ± 3.2 lbs, compared with the uninvolved shoulder at 23.1 ± 2.5 lb (p = 0.525). The average Constant score of the involved shoulder was 91.7 ± 4.2 points (range 82 to 96 points) (Table 2). All patients were satisfied with the results. No complications such as a winging scapula or brachial plexus palsy were noted. We evaluated whether age influenced the surgical outcome and found no significant correlation between age at the time of the operation and functional outcome in our patients (p = 0.397).

DISCUSSION

Failure of the scapula to descend between the 9th and 12th weeks of intrauterine life has been proposed to induce congenital elevation of the scapula.[7] An

Table 1. Pertinent Patient Data

Case	Gender	Age (yrs)	Side	Associated deformity	Omovertebral connection
1	F	4	L	Lumbar scoliosis	Yes
2	F	11	L	nil	Yes
3	F	4	L	T-L spine scoliosis	Yes
4	M	4	R	nil	FC
5	F	9	L	bifurcation of C6	Yes
6	M	4	R	Hydrocephalus and polydactyly	Yes
		5	L		Yes
7	F	11	L	C5 and T3 hemivertebrae, congenital torticollis, hypothyroidism	Yes
8	M	5	L	C7 hemivertebrae	Yes

Abbreviations: F: female; M: male, L: left; R: right; FC: Fibrocartilage connection.

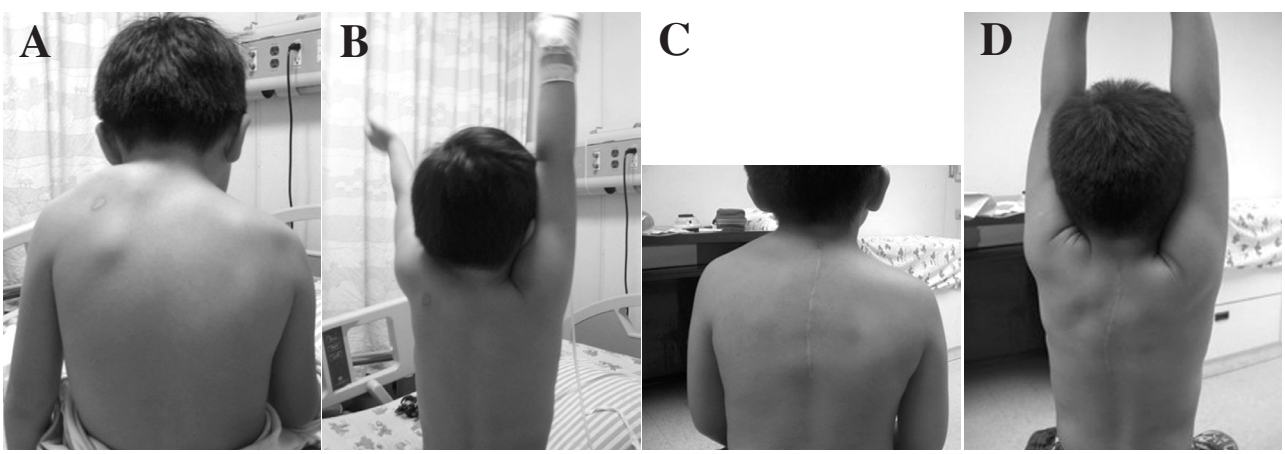

Fig. 3 Photographs of the cosmetic appearance and abduction motion of the shoulder before (A and B) and after (C and D) the Woodward procedures. The patient has improvement in cosmetic appearance and abduction motion from 130 degrees preoperatively to 170 degrees 80 months after surgery.

omovertebral connection consists of fibrous bands, cartilage and/or bone.[8] This is supposed to be an abnormal development of the epiphysis at the vertebral border of the scapula. Tethering by the omovertebral connection produces a traction force and deforms the scapular shape during development.[9] Among our patients, 8 shoulders (88.9%) had a bony connection, and one had a fibrocartilage connection.

Preoperatively, the deformed scapula has a decreased height-to-width ratio in comparison with the contralateral side. We speculated that the limited motion and weak strength in abduction of the shoulders of our patients may have been caused by a hypoplastic scapula, omovertebral connection and non-descending alignment. We found that a preoperative CT scan or MRI study provided useful imaging for a scapuloplasty. The scapula could be corrected to a normal height-to-width ratio range. MRI was used in 2 patients in our series. In addition to the bony structures, dedicated soft tissue imaging was noted on MRI. The MRI studies provided additional information such as fibrocartilage connections, muscular atrophy, the contours of the trapezius and rhomboid muscles, and associated nervous system anomalies. CT scanning is cost-effective and might be better for geographical analysis, but radiation exposure is a concern. To improve abduction and mobilization of the operated scapula, the omovertebral connection was excised. Thus, the scapula was lowered 2.2 cm, and that status was maintained

Table 2. Radiographic Appearance and Shoulder Function after Long-term Follow-up

Case	Follow-up (months)	Height width ratio			Superior displacement ratio (%)		Scapular lowering (cm)	Cavendish grade		Abduction (degrees)		Abduction power (pounds)		Constant score
		Normal side	Affected side											
			Pre-op	Follow-up	Pre-op	Follow-up		Pre-op	Follow-up	Pre-op	Follow-up	Operative side	Normal side	
1	137	2.0	1.6	2.0	0.6	0.4	1.9	3	2	125	165	23	26	92
2	140	1.3	1.3	1.4	0.4	0.2	2.0	3	2	140	180	21	25	92
3	136	1.9	1.7	1.8	0.5	0.1	2.4	4	1	100	170	20	24	96
4	89	1.5	1.1	1.5	0.6	0.1	4.8	3	1	130	155	23	24	90
5	87	1.7	1.3	1.7	0.2	0.1	3.1	3	1	130	175	15	19	82
6 (R)	135	A	1.2	1.4	N	N	0.9	4	1	120	140	24	A	96
(L)	139	A	1.3	1.5	N	N	0.9	4	1	125	125	22	A	94
7	78	1.6	1.1	1.6	0.4	0.2	2.1	3	1	100	130	25	25	92
8	80	1.6	1.3	1.5	0.4	0.2	1.8	3	1	130	170	23	20	91
	113±29	1.6±0.2	1.3±0.2	1.6±0.2	0.5±0.1	0.2±0.1	2.2±1.2			122±14	157±20	21.8±3.2	23.1±2.6	91.7±4.2

Abbreviations: N: not measured; A: measured as affected side.

throughout the follow-up period. We suggest that a pre-operative CT scan or MRI study is useful to assist surgeons in correcting the affected scapula to a normal height-to-width ratio in the scapuloplasty procedure.

Surgical correction of a Sprengel deformity is a complex procedure. The optimal age for surgery is between 4 years and 6 years old.[10] The average age of our patients at the time of the operation was 6 years. We found no significant correlation between age at operation and functional outcome ($p = 0.397$). Caudal movement of the scapula reportedly increases the risk of brachial plexus.[11] Surgical correction has also been found to increase the risk of dorsal scapular nerve injury.[12] A clavicular osteotomy has been performed to diminish neurovascular compression, especially in severe cases in older patients.[13] In this study, we did not perform a clavicular osteotomy in any of the patients. No brachial plexus injury or winging scapula was observed postoperatively. We propose that excision of the omovertebral connection followed by a scapuloplasty and proper but not forceful caudal relocation of the scapula may circumvent the possibility of neurological complications.

The Woodward procedure has been used for correction of Sprengel deformity.[4] Satisfactory results have been documented after long-term follow-up.[3] However, few studies have reported the functional outcome after a Woodward procedure. In our study, we found improvement in abduction, Cavendish grading, and the functional Constant score after long-term follow-up. All patients were satisfied with the surgical results. The muscle power in all affected shoulders recovered nearly to the level of the unaffected side after the Woodward procedure. We suggest that restoration of the affected scapula toward the anatomically correct level may improve abduction of the shoulder.

In conclusion, preoperative 3D CT or MRI evaluation was beneficial for planning a scapuloplasty. The Woodward procedure offers substantial improvement of shoulder function and cosmetic appearance for patients with Sprengel deformity.

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Woodward 手術法有效改善 Sprengel 氏畸形之肩功能

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背 景： Sprengel 氏畸形即先天性肩胛骨高位症，主要引起肩關節外展活動受限及外觀上的缺陷。雖然文獻上 Woodward 手術法之報告均有理想之矯正效果，但仍缺乏術後長期功能預後之研究。本研究分析八位 Sprengel 氏畸形病患接受 Woodward 手術法後之外觀及功能上之改善。

方 法： 我們評估接受 Woodward 手術法之八位 Sprengel 氏畸形病患 (九個肩膀)。我們利用 Cavendish 評分系統及 Constant 功能評分來評估肩關節之功能改善；同時記錄外觀、肩關節活動角度以及 X 光之變化。診斷工具主要以電腦斷層或核磁共振檢查。

結 果： 八位病人平均追蹤 113 ± 29 個月，Cavendish 外觀評分均有統計上之改善 (p = 0.000)。上端移位比例從 0.5 ± 0.1 減少至 0.2 ± 0.1 (p = 0.004)；患側肩胛骨之高寬比例從 1.3 ± 0.2 (1.1 to 1.7) 增加至 1.6 ± 0.2 (1.4 to 2.0) (p = 0.001) 術後與健側 1.6 ± 0.2 (1.3 to 2.0) (p = 0.821) 之比較無統計上之差異。肩關節外展活動度從 122 ± 14 (100 to 140) 度增加至 157 ± 20 (125 to 180) 度 (p = 0.008)。患側平均外展肌力爲 21.8 ± 3.2 lb，與健側 23.1 ± 2.5 lb (p = 0.525) 之比較無統計上之差異。平均之 Constant 功能評分爲 91.7 ± 4.2 分。

結 論： Woodward 手術法能有效的改善 Sprengel 氏畸形病患之外觀及肩功能。
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關鍵詞： 先天性肩胛骨高位症，Woodward 手術法

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