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ORIGINAL PAPER

Spinal deformity after multilevel osteoplastic laminotomy

Peter Raab · Krauss Juergen · Harald Gloger · Nils Soerensen · Alexander Wild

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Abstract Multilevel laminectomy in children has a significant rate of postoperative spinal deformity. To decrease the incidence of this complication, the use of osteoplastic laminotomy is advocated to minimise the risk of spinal deformity by preserving the normal architecture of the spine. In this retrospective study, a 10-year series of a paediatric population undergoing multilevel osteoplastic laminotomy is reviewed to determine the incidence, especially in contrast to laminectomies, and to identify factors that affect the occurrence of spinal column deformity. Seventy patients (mean age 4.2 years) underwent multilevel osteoplastic laminotomy for congenital anomalies or removal of spinal tumours. All patients had a clinical and radiographic examination preoperatively, 12 months postoperatively and at follow-up. Mean follow-up was 5.3 years (range 3–12.6 years). Nineteen patients (27%) had a new or progressive spinal deformity. There was an increased incidence in patients who had surgery for spinal tumours ($P<0.05$), surgery of the cervical spine ($P<0.01$), and who had more than five levels of the spine included ($P<0.05$). A review of the literature on children with multilevel laminectomy ($n=330$), the incidence of spinal deformity found a significantly higher (46%) compared to our study group. This study demonstrates that osteoplastic laminotomy was found to be very effective in decreasing the incidence of spinal deformities after spinal-canal surgery for spinal-cord tumours or congenital anomalies in children and adolescents. The choice of an anatomical reconstructive surgical technique such as osteoplastic laminotomy seems to be essential to minimise secondary problems due to the surgical technique itself. Nevertheless, growing patients should be followed up for several years after the initial operation for early detection and consequent management of any possible deformity of the spinal column.

Résumé La laminectomie étagée chez l'enfant entraîne un taux important de déformations rachidiennes post-opératoires. Pour diminuer l'incidence de cette complication nous utilisons la laminotomie ostéoplastique qui sert à préserver une architecture normale du rachis. Dans cette étude rétrospective, une série d'enfants a été revue sur 10 ans de façon à déterminer l'incidence de ces déformations en comparaison avec la laminectomie. 70 patients (âge moyen 4,2 ans) ont bénéficié d'une laminotomie ostéoplastique pour anomalie congénitale ou pour résection tumorale. Les patients ont bénéficié d'un suivi clinique et radiographique, le suivi moyen a été de 5,3 ans (de 3 à 12,6 ans). 19 patients (27%) ont présenté une déformation progressive du rachis. Celle-ci est plus importante dans les résections pour tumeurs ($P<0.05$) et au niveau de la colonne cervicale ($P<0.01$) et lorsque 5 niveaux ont été inclus sur le plan chirurgical ($P<0.05$). La revue de la littérature à propos de 330 laminectomies a montré une incidence des déformations rachidiennes de 46% comparé au 27% de notre série. Cette étude démontre que la laminotomie ostoplastique est une chirurgie qui diminue l'incidence des déformations rachidiennes après chirurgie

P. Raab (✉) · H. Gloger
Department of Orthopaedics, University of Wuerzburg,
Wuerzburg, Germany
e-mail: p-raab.klh@mail.uni-wuerzburg.de

K. Juergen · N. Soerensen
Section of Paediatric Neurosurgery, Department of Neurosurgery,
University of Wuerzburg,
Wuerzburg, Germany

A. Wild
Department of Orthopaedics, Hessing Klinik,
Ausburg, Germany

pour malformation ou tumeur. Néanmoins, ces patients devront être surveillés pendant toute la période de croissance de façon à détecter une déformation éventuelle.

Introduction

Congenital anomalies and tumours of the spine are rare in children. Surgical management of these entities predisposes patients to multiple postoperative problems. The most common musculoskeletal complication after extensive multilevel laminectomies to remove spinal tumours or treat congenital anomalies is spinal-column deformity, including kyphosis, scoliosis, lordosis and combined deformities, with a reported incidence of more than 50% [4, 7, 10, 15, 21]. In an attempt to minimise the risk of postoperative spinal deformity, Raimondi et al. (1976) introduced and advocated the use of osteoplastic laminotomy. This procedure preserves the normal architecture of the spine in patients who are still developing and theoretically may decrease the incidence of spinal-column deformity [8, 11, 16].

The purpose of this study was to analyse our experience with the mid-term clinical and radiographic outcome of children who had multilevel osteoplastic laminotomies of the spine for removal of intraspinal tumours or to treat congenital anomalies and to identify factors affecting the occurrence of postlaminotomy deformity of the spine.

Materials and methods

We reviewed the records of all children treated with multilevel osteoplastic laminotomy between the years 1987 and 1997. Seventy consecutive patients (mean age 4.2 years, range: 10 days to 13.8 years) operated up on during the 10-year period were included in the study. Pre- and postoperative radiographs, computed tomography, magnetic resonance imaging and all surgical records were used to determine diagnosis, localisation and extent of the osteoplastic laminotomy.

Laminotomy was performed by separating muscle and ligamentous attachments from the spinal arches leaving the periosteum and interspinous ligaments intact. Dissection was carried laterally to just beyond the articular facets. Then the inferior interspinous ligament of the laminar flap was cut.

Laminar osteotomy was done with an oscillating saw with a blade 0.3-mm thick, just medial to an imaginary line separating the pedicle from the lamina. When the laminae were all freed by cutting the yellow ligaments bilaterally, the laminar flap was reflected superiorly and sometimes temporarily removed by cutting the superior interspinous ligament, especially in the earlier cases. After interspinal surgery was completed, the laminar flap was brought into its anatomical position and fixed with transosseous sutures. Completing the reconstruction of the laminar flap, interspinous ligaments were adapted and muscle insertions reconstructed segment-wise. All patients were discharged immobilised in a cast for 6 weeks to assure bony bridging and to minimise pseudarthrosis. Clinical and radiological follow-up was performed on a yearly basis in our institution. Follow-up ranged from 3–12.6 years, with a mean follow-up length of 5.3 years.

Each patient was classified according to pre- to postoperative changes in the clinical and radiographic status. Thus four different categories of deformity could be defined, and the patients could be grouped depending on the diagnosis (CA: congenital anomaly, ST: spinal tumour). In group A, patients had no pre- and postoperative deformity; in group B, a pre-existing deformity was unchanged or better postoperatively. Patients of these two groups (A and B) were considered to have had a good result. In group C, all patients had a new postoperative deformity, and group D included patients with a pre-existing deformity that worsened after surgery. Groups C and D represent an unsatisfactory result (Table 1).

Deformities were measured on upright anteroposterior and lateral films using the Cobb method. Thoracic kyphosis was measured from the upper endplate of T2 to the lower endplate of T12, lumbar lordosis from the upper endplate of T12 to the endplate of S1 [3, 19].

To evaluate the development of the spinal deformity over time, the results were analysed for each postoperative year. To determine whether osteoplastic laminotomy is superior to the traditional laminectomy in terms of preventing spinal deformity, a survey of the literature was conducted taking into account all studies with a study group of more than 10 patients and with a maximum age of 18.

Two studies on laminectomies in children could be found in the literature (Yasuoka: $n=26$ and Papagelopoulos: $n=12$) in which the occurrences of spinal deformities were evaluated, so that an estimate on the incidence of postoperative deformity was possible and could be compared with our data [15, 21].

For statistical analysis, the chi-square test for independence, Fisher's exact test and the Tukey-Kramer method for

Table 1 Classification of patients pre- and postoperatively according to clinical and radiographic changes

	Preoperative	Postoperative
Group A	No deformity	No deformity
Group B	Preexisting deformity	Unchanged or better
Group C	No deformity	New deformity
Group D	Preexisting deformity	Progressive deformity

post hoc analysis were used. Kaplan-Meier estimates were used to measure the theoretical probability of occurrence of a postoperative spinal deformity over time. Statistical tests were considered significant when $P<0.05$. The SPSS statistical software program (SPSS, Chicago, IL, USA) was used for this analysis.

Results

Our study group consisted of 35 children with spinal cord tumours and 35 children with other cutaneous, neural or osseous anomalies of the spine (Table 2). The group consisted of 31 male and 39 female patients with slight predominance of the female gender in the group of congenital anomalies. The extent of laminotomy was similar in both groups ranging from 2–13 levels (average: 3.8 CA, 4.9 ST). Osteoplastic laminotomy was performed in the cervical spine in 6 patients, in the cervicothorax in 9 patients, in the thoracic spine in 15 patients, in the thoracolumbar region in 12 patients, and in the lumbar region in 28 patients. All operations in the cervical spine were for spinal tumours, most of the patients operated on in the lumbar spine had congenital anomalies.

Table 2 Distribution of pathology

Spinal tumours	*n*
Astrocytoma	
I° (Pilocytic astrocytoma)	10
II°	6
III°	3
IV° (Glioblastoma)	1
B-cell lymphoma	
Highly malignant	1
Ependymoma	
II°	1
IV°	1
Ganglioglioma	2
Neurinoma	1
Neuroblastoma	
III°	1
IV°	2
Neurofibroma	1
Neurofibrosarcoma	2
Primitive neuroendothelial tumour (pnet)	1
Teratoma	2
Total	35
Congenital anomalies	
Dermal sinus	9
Intraspinal lipoma	14
Intraspinal cysts	4
Meningomyelocele	8
Total	35

With regard to the clinical and radiological parameters, 51 children (73%) had good results with no deformity or no progression of a pre-existing deformity (groups A and B). Nineteen children (group C and D) showed an unsatisfactory result (27%) with a newly established deformity (average of 22.9° for scoliosis and 62° for kyphosis) or progressive deformity (deterioration of 17.5° on average for scoliosis and 16° for kyphosis). No pseudarthrosis was detected with plain radiographs. Children treated for spinal tumours had an unsatisfactory result in 40% of cases. In contrast, only 14% of the children treated for congenital anomalies had an unsatisfactory result.

Risk factors for spinal deformity

The statistical evaluation showed that the underlying diagnosis of a spinal tumour ($P<0.05$) and the localization of the operation in the cervical spine ($P<0.05$) had a significant influence on the likelihood of a postoperative spinal deformity. Furthermore the extent of the operation beyond five levels ($P<0.05$) and revision surgery ($P<0.01$) were significant risk factors for developing a spinal deformity.

The theoretical probability of developing a postoperative spinal deformity after multilevel osteoplastic laminotomy was estimated in the congenital anomaly group for the first postoperative year at just under 10%, increasing to 14% in the third year and showed no further progress up to the seventh postoperative year. In the group with spinal tumours, the probability in the first year was 26%, increasing steadily up to 55% in the sixth year and remained there up to the ninth postoperative year.

Taking into account the review of the literature (eight studies, children: $n=330$), the incidence of spinal deformity in patients undergoing multilevel laminectomy was 46% on average, even considering that many patients with risk factors like malignant spinal tumours or surgery of the cervical spine were excluded from some of these studies. This is significantly higher compared to the incidence of 27% in children in our study group who underwent multilevel osteoplastic laminotomy (Table 3).

Discussion

Spinal deformity associated with multilevel laminectomy done for a variety of reasons (usually spinal cord tumours in young children) has been reported in the neurosurgical and orthopaedic literature to be 24–100%. Lonstein's review of the literature estimates the incidence of spinal-column deformity resulting from laminectomy in patients under 19 years of age to be about 50% [9].

According to Cattell and Clark (1978), in young individuals spinal stability depends on balanced growth of

Table 3 Studies on multilevel laminectomy in children ($n>10$; age<18 years)

Author, year	*n*	*n* (def.)	Incidence	Remarks
Haft, 1959	17	10	58.8%	Patients with metastasis, congenital anomalies excluded
Tachdijan, 1965	115	30	26.1%	No exclusion criteria
Boersma, 1969	51	25	49%	No exclusion criteria
Dubousset, 1970	55	43	78.2%	No exclusion criteria
Fraser, 1977	29	10	34.5%	Only tumor patients
Yasuoka, 1982	26	12	46.2%	Patients with metastasis, congenital anomalies and cervical localization excluded
Lunardi, 1993	25	15	60.0%	Only tumor patients
Papagelopoulos, 1996	12	6	50.0%	All patients with preexisting deformity excluded
Total	330	151	Mean: 45.9%	

n (def.) Number of patients with postoperative spinal deformity

bony structures, ligaments and paravertebral musculature. Skeletal and ligamentous deficiencies and muscular imbalance after multiple laminectomies will result in a progressive osseous deformity consequent to bone growth [2]. Furthermore, the role of facet joints in spinal stability was emphasised clinically [4] and in animal and cadaver experiments [5, 13, 14]. Injury of these structures predisposes the patient to spinal-column instability and promotes spinal deformity, often with a rotatory component. Thus it is recommended that during laminectomy the facet joints be preserved in their entirety if possible [15, 17]. To avoid the complication of instability and deformity of the spine following of laminectomy, the possibility of performing anterior fusion before extensive laminectomy or posterolateral fusion at the time of laminectomy has been discussed [2, 18].

In an effort to reduce potential destabilisation of the spine and the necessity for more extensive surgery, osteoplastic laminotomy was introduced by Raimondi et al. in 1976 and adopted by Milhorat in 1978 for selected patients. In this procedure, the laminae are separated from the posterior elements and mobilised as a flap to provide access to the spinal cord. After surgical intervention, the flap is replaced and stabilised with sutures in the hope of preserving stability. The surgical technique of osteoplastic laminotomy may have some benefit in preventing spinal deformity, especially when treating young patients with remaining growth potential; however, its effectiveness has not been established [12, 16].

In this retrospective study, a 10-year series of a paediatric population undergoing multilevel osteoplastic laminotomy was reviewed to evaluate the rate of postoperative spinal deformity. The incidence of new or progressive spinal deformity of the entire population was 27.1%.

It is generally accepted that the younger the patient, the more likely the occurrence of spinal deformity is [10, 20, 21]. This correlation was not evident in our population because there was no significant difference in the mean age between the different study groups.

On the other hand there was a significant difference concerning the underlying diagnosis. The amount of postoperative new or progressive deformity in the group with spinal tumours was 2.8 times higher than in the group with congenital anomalies.

In the literature it has been stated that localisation and extent of surgery influence the rate of postoperative deformity. In our study, surgery of the cervical spine resulted in significantly worse clinical and radiological results, similar to the results observed in patients having laminectomy in this anatomical location. A retrospective survey Fraser (1977) of 40 children, most of them treated for spinal tumours at the thoracic and lumbar level, showed spinal deformity in 34.5%. Lunardi (1997) reviewed 25 patients with spinal tumours where the localisation was in the cervicothorax in 68% and who had a 60% incidence of spinal deformity. This supports the statement that the higher the level of the lesion, the greater is the likelihood of deformity after surgery [5, 10].

In contrast to studies that show a significant difference in results when laminectomy was performed at more than two levels, a significant difference in the occurrence of spinal deformity in this study was observed when surgery of more than four levels was performed. This difference between the extent of surgical treatment and spinal deformity underlines the use of osteoplastic laminotomy in patients, who need a more extended surgical access to the spine [2, 15].

In a review of the literature, the incidence of a new or progressive deformity in children treated by laminectomy (n=330) was considerably higher (46%) compared to our study group (n=70; incidence: 27.1%), despite the more extensive exclusion criteria established in these papers, which implied that more favourable postoperative results could have been expected [1, 4–6, 10, 15, 20, 21].

With the use of the reports of Yasuoka and Papagelopoulos (n=38) on the time-dependent occurrence of spinal deformities after laminectomy in children, the theoretical risk of developing a deformity for children with congenital abnormalities was determined to be 15% in the first year postoperatively, and increased up to 40% over the course of 6 years (our study: first year: 10%; 14% up to the seventh year). For children with tumours, the theoretical risk of developing a spinal deformity was determined to be 65% within 6 years considering the two reports, compared with 55% in our study. Taking these figures into account it seems that children with osteoplastic laminotomy have a better outcome over time [15, 21].

Conclusion

The paediatric spine is in a state of dynamic flux, with tensile and compressive forces in exquisite balance during growth and development. Any disruption of the posterior elements may create unbalanced forces that progress to radiographic, and ultimately clinically significant deformity of the spine. In addition to criteria that affect the development of spinal deformities, such as the surgical technique, there are many things that cannot be influenced to prevent this complication, including localisation and extent of the region to be operated on, age of the patient and the underlying disease itself. Therefore the choice of an anatomical reconstructive surgical technique is essential to minimise secondary problems due to the technique itself.

This study demonstrated that osteoplastic laminotomy was very effective in diminishing the development of spinal deformities after spinal-canal surgery for spinal-cord tumours or other diseases in children and adolescents. Nevertheless growing patients should be followed up for several years after the initial operation for early detection and consequent management of any possible deformity of the spinal column.

References

1. Boersma G (1969) Curvatures of the spine following laminectomies in children. Born, Amsterdam
2. Cattell HS, Clark GL Jr (1978) Cervical kyphosis and instability following multiple laminectomies in children. J Bone Joint Surg Am 49:713–720
3. Cobb J (1948) Outline of the study of scoliosis. AAOS Instr Course Lect 5:261–275
4. Dubousset J (1973) Paper presented to neurosurgical congress of infants. In Rougerie, L (ed) Compressions medullaires non-traumatique de l'enfant. Paris
5. Fraser RD, Patterson TL (1977) Orthopaedic aspects of spinal cord tumors in children. J Bone Joint Surg Br 59:143–146
6. Haft H, Ransohoff J, Carter S (1959) Spinal cord tumors in children. Pediatrics 23:1152–1159
7. Houten JK, Weiner HL (2000) Pediatric intramedullary spine cord tumors: special considerations. J Neurosurg Oncol 47:225–230
8. Kawai S, Sunago K, Doi K, Saika M, Tagucchi T (1988) Cervical laminoplasty (Hattori's method). Spine 13:1245–1250
9. Lonstein JE (1978) Postlaminectomy kyphosis. In: Chou SN, Seljeskog EL (eds) Spinal deformities and neurological dysfunction. Raven Press, New York
10. Lunardi P, Licastro G, Missori P, Ferrante L, Fortuna A (1993) Management of intramedullary tumors in children. Acta Neurochir 120:59–65
11. Miyazaki K, Tada K, Matsuda Y, Okuno M, Yasuda T, Murakami H (1998) Posterior extensive simultanous multisegment decompression with posterolateral fusion for cervical instability and kyphotic and/or s-shaped deformities. Spine 14:1160–1170
12. Milhorat TH (1978) Pediatric neurosurgery. Contemp Neurol Ser 16:611–623
13. Munechica Y (1973) Influence of laminectomy on the stability of the spine: an experimental study with special reference to the extent of laminectomy and the resection of the intervertebral joint. J Jpn Orthop Assoc 47:111–126
14. Panjabi MM, White AA III, Johnson RM (1975) Cervical spine mechanics as a function of transection of components. J Biomech 8:327–336
15. Papagelopoulos PJ, Peterson HA, Ebersold MJ, Emmanuel PR, Choudhury SN, Quast LM (1997) Spinal deformity and instability after lumbar or thoracolumbar laminectomy for intraspinal tumors in children and young adults. Spine 22:442–451
16. Raimondi AJ, Guitierrez FA, Di Rocco C (1976) Laminectomy and total reconstruction of the posterior spinal arch for spinal canal surgery in childhood. J Neurosurg 45:555–560
17. Sharma M, Langrana N, Rodriguez J (1995) Role of ligaments and facets in lumbar spinal stability. Spine 20:887–900
18. Smith GW, Robinson RA (1958) The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. J Bone Joint Surg Am 56:607–624
19. Stagnara P, De Mauroy JC, Dran G, Gonon GP, Costanzo G, Dimnet J, Pasquet A (1982) Reciprocal angulation of vertebral bodies in a sagittal plane: approach to reference for the evaluation of kyphosis and lordosis. Spine 7:335–342
20. Tachdjian MO, Matson DD (1965) Orthopaedic aspects of intraspinal tumors in infants and children. J Bone Joint Surg Am 47:223–248
21. Yasuoka S, Peterson HA, MacCarthy CS (1982) Incidence of spinal column deformity after multilevel laminectomy in children and adults. J Neurosurg 57:441–445