Assessment of the usefulness of X-ray myelography and magnetic resonance myelography, performed with an open low-field device, in diagnosing perinatal preganglionic injuries of the brachial plexus

Jerzy Gosk[1], Barbara Hendrich[2], Roman Wiącek[1], Marek Sąsiadek[2,3], Roman Rutowski[1,4]

[1]Department of Traumatology, Clinic of Traumatology and Hand Surgery, Wroclaw Medical University, Poland
[2]Department of General and Interventional Radiology and Neuroradiology, Academic Teaching Hospital, Wroclaw, Poland
[3]Chair of Radiology, Wroclaw Medical University, Poland
[4]Department of Biostructure, Department of Sport Medicine and Nutrition, University of Physical Education, Wroclaw, Poland

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Corresponding author:
Jerzy Gosk MD
Department of Traumatology,
Clinic of Traumatology
and Hand Surgery
Wroclaw Medical University
213 Borowska
50-556 Wroclaw, Poland
Phone: +48 71 734 38 00
Fax: +48 71 734 38 09
E-mail:
chiruraz@am.wroc.pl

Abstract

Introduction: The goal is to assess the usefulness of diagnostic imaging in diagnosing perinatal preganglionic injuries of the brachial plexus.
Material and methods: The clinical material included 40 children of both genders, aged 2 to 35 months. The authors analysed the results of diagnostic imaging examinations (myelography in 20 cases and magnetic resonance [MR] myelography in 20 cases), intraoperative view and clinical course.
Results: In 13 out of 40 (32.5%) examined children, no evidence of avulsion of the roots of the spinal nerves was found either by diagnostic imaging or during the surgery. In 3 cases (7.5%) with avulsed roots of the spinal nerves, the diagnostic imaging and intraoperative appearance were in agreement. Total agreement of the diagnostic imaging and intraoperative view was found in 40% of cases. In 9 patients (22.5%) suspected avulsion of roots of the spinal nerves was not confirmed during the surgery. However, the further clinical course of the disease in these cases indicated high probability of avulsion of roots without their pull-out from the intervertebral foramens. In the remaining cases, the findings were as follows: false positive results – 7 (17.5%), false negative results – 1 (2.5%), results underestimating injury – 3 (7.5%), results overestimating injury – 2 (5%).
Conclusions: It was determined that the usefulness of pre-operative diagnostic imaging is limited. Due to the risk of occurrence of false positive and false negative results, final decisions concerning selection of the surgical technique must be based on the analysis of the intraoperative view and preoperative clinical symptoms.

Key words: brachial plexus, diagnostic imaging, spinal nerve root avulsion, perinatal injury.

Introduction

The goal of diagnostic imaging in diagnosing perinatal injuries of the brachial plexus is mainly to differentiate between preganglionic and postganglionic injuries of the brachial plexus [1-3]. Diagnostic imaging in children requires deep sedation or general anaesthesia because of the patients' uncontrollable movements [1, 4]. Interpretation of the results may be more difficult than in adults because of pulsation of the cerebrospinal fluid and the necessity to assess the small area of interest [1]. Radiological protection of small patients excludes repeated exposure in the case of unsatisfactory quality of films. X-ray myelography is an invasive technique, requiring administration of the contrast agent into the spinal canal and general anaesthesia. Computed tomography (CT) myelography involves greater exposure to ionising radiation than in the case of X-ray myelography. Magnetic resonance imaging is a non-invasive method which does not involve exposure to ionising radiation. It is useful for diagnosing preganglionic injuries and it visualises peripheral parts of the brachial plexus [1, 5-8].

Material and methods

The clinical material included 40 children of both genders (21 boys and 19 girls) aged from 2 months to 35 months (mean age: 8.57 months) with perinatal injury of the brachial plexus, who were qualified for diagnostic imaging within pre-surgery diagnostics between 1998 and 2006. Initially conventional X-ray myelography of the cervical spine used to be performed after fluoroscopy-guided administration of the contrast agent into the spinal canal. Suboccipital puncture was applied in most cases and lumbar puncture in a few cases. Two to ten ml of contrast of concentration of 270 mg I/ml (metrizamide) or 240 I/ml (monomer iohexol and dimer iotrolan) were administered, the quantity of used contrast agent depending on the child's weight. Only anterio-posterior films of the cervical spine were made, including the cervical-thoracic border zone (Figure 1). For the same reason CT myelography used to be performed (with TUR 800 or SIREGRAF device) immediately after the myelography only in the cases of insufficient quality of radiographs. Later, MR myelography (myelo-MRI) examination, as an entirely non-invasive method, replaced X-ray myelography completely. Myelo-MRI was performed with a low-field device (low-field open device: MR OUTLOOK PREVIEW – 0,23 T – Marconi Medical Sytrunk). The fast spin-echo 2D (FSE 2D) sequence was applied with the following parameters: TR 5000 ms, TE 308 ms, FA 90°, slice thickness 3.0/3.5 mm, partition number 6 or 12, acquisition time 4 and 8 min respectively. Longitudinal and transverse MIP reconstructions were performed. A total of 20 X-ray myelographic examinations (supplemented by CT myelography in two cases) and 20 myelo-magnetic resonance imaging (MRI) examinations were performed. Images studies (X-ray myelography, MRI myelography) were evaluated by two neuroradiologists (B.H., M.S.) who were blinded to all clinical information (side of injury, clinical history, results of neurological examination, results of surgery and intraoperative findings). The diagnostic imaging results and intraoperative view were analysed. In the cases of discrepancies between the result of a diagnostic imaging study and intraoperative view, restoration of the function dependent on localization of the point suspected of preganglionic injury was assessed (applying commonly accepted evaluation scales) [9]. The post-operative follow-up ranged from 3 to 11 years. The sensitivity and specificity of diagnostic images were established.

Statistical analysis

The statistical analysis was performed using the program Statistica 8.0. The differences between X-ray myelography and MR myelography were assessed by χ^2 test.

Results

The analysis revealed 13 normal results (no evidence of spinal nerve root avulsion) of diagnostic imaging (8 X-ray myelographic examinations and 5 myelo-MRI studies), and in all those cases intra-

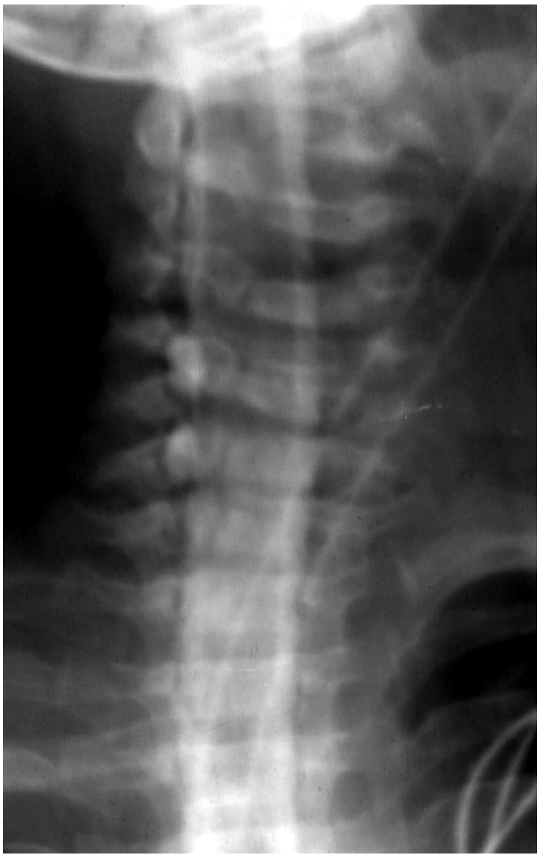

Figure 1. Myelography in child (anaesthetic accessories are visible); pseudomeningoceles on the right side – level C5/C6 and C6/C7

Table I. Analysis of the cases of agreement of the diagnostic imaging and intraoperative view

No.	Clinical appearance of the injury	Type of diagnostic imaging	Result of the diagnostic imaging	Intraoperative view	Interpretation
1	Upper	Myelography	No evidence of avulsion	Rupture of C5, compression of C6 and upper trunk	Agreement of results
2	Upper-middle	Myelography	No evidence of avulsion	Compression of the upper and middle trunk	Agreement of results
3	Upper-middle	Myelography	No evidence of avulsion	Neuroma of the continuity of the upper and middle trunk	Agreement of results
4	Upper-middle	Myelography	No evidence of avulsion	Rupture of the upper trunk, compression of the middle trunk	Agreement of results
5	Upper-middle	Myelography	No evidence of avulsion	Compression of the upper and middle trunk	Agreement of results
6	Complete	Myelography	No evidence of avulsion	Neuroma of the continuity of the upper and middle trunk, compression of the lower trunk	Agreement of results
7	Complete	Myelography	No evidence of avulsion	Compression of the trunks of the plexus	Agreement of results
8	Complete	Myelography	No evidence of avulsion	Rupture of the upper trunk, compression of the middle and lower trunk	Agreement of results
9	Complete	Myelography	Avulsion of C6, C7	Rupture of C5, avulsion of C6 and C7, compression of the lower trunk	Agreement of results
10	Upper-middle	Myelo-MRI	No evidence of avulsion	Compression of the upper and middle trunk	Agreement of results
11	Upper-middle	Myelo-MRI	No evidence of avulsion	Compression of the upper and middle trunk	Agreement of results
12	Complete	Myelo-MRI	No evidence of avulsion	Compression of the trunks of the plexus	Agreement of results
13	Complete	Myelo-MRI	No evidence of avulsion	Neuroma of the continuity of the upper and middle trunk, compression of the lower trunk	Agreement of results
14	Complete	Myelo-MRI	No evidence of avulsion	Rupture of C5, C6, C7, compression of the lower trunk	Agreement of results
15	Complete	Myelo-MRI	Avulsion of C6	Rupture of C5, C7, avulsion of C6, compression of the lower trunk	Agreement of results
16	Complete	Myelo-MRI	Avulsion of C7, C8	Rupture of the upper trunk, avulsion of C7, C8, compression of Th1	Agreement of results

operatively no signs of a preganglionic injury were observed. In a further 3 cases avulsion of roots of the spinal nerves was found in diagnostic imaging and confirmed intraoperatively. These cases concerned avulsion of the roots of spinal nerve C6 and C7 (myelography), avulsion of the roots of spinal nerve C6 (MR myelography), and avulsion of roots of spinal nerve C7 and C8 (MRI myelography) – Table I. Discrepancies between results of the myelographic studies and intraoperative view are discussed in Tables II and III. The comparison of the efficacy of diagnostic imaging (X-ray myelography and MRI myelography) in relation to the intraoperative view is shown in Table IV.

In 9 cases, the further clinical course indicated the possibility of the potential avulsion of roots of the spinal nerves at C8-Th1, as suggested by the diagnostic imaging studies. However, no clear evidence of avulsion was found intra-operatively in these cases. The patients' data are shown in Table V.

The sensitivity of X-ray myelography was 78%, and the specificity was 93%. The sensitivity of MRI myelography was 64%, and the specificity was 94%.

Discussion

The diagnostic studies have been performed only in children qualified for surgical treatment based on the clinical view of injury. Twenty-eight of 40 chil-

Table II. Analysis of discrepancies between the myelo-MRI result and intraoperative view considering further clinical course

No.	Clinical appearance of the injury	Diagnostic imaging	Intraoperative view	Return of function	Interpretation
1	Upper-middle	Avulsion of C6	Rupture of the upper trunk	Improved function	False positive result
2	Upper-middle	Avulsion of Th1	No evidence of avulsion	Normal function	False positive result
3	Upper-middle	Avulsion of C7, C8	Avulsion of C7; C8 in the foramen	Improved function	Overestimated result
4	Upper-middle	Avulsion of C6, C7 and possibly C5	No evidence of avulsion	Improved function	False positive result
5	Complete	Avulsion of C8, Th1	Avulsion of C7; C8, Th1 in the foramens	Poor function	Possible avulsion
6	Complete	Avulsion of C8, Th1	Avulsion of C7; C8, Th1 in the foramens	Poor function	Possible avulsion
7	Complete	Avulsion of C8, Th1	No evidence of avulsion	Poor function	Possible avulsion
8	Complete	Avulsion of Th1	No evidence of avulsion	Poor function	Possible avulsion
9	Complete	Avulsion of C5, C6, C7, C8	Avulsion of C6, C7, C8; rupture of C5	Improved function	Overestimated result
10	Complete	Avulsion of C6, C7	Avulsion of C5, C6, C7	Poor function	Underestimated result
11	Complete	Avulsion of C7, C8	Avulsion of C7; C8 in the foramen	No data	No data
12	Complete	Avulsion of C8, Th1	No evidence of avulsion	Poor function	Possible avulsion
13	Complete	Avulsion of C6, C7, C8	Avulsion of C5, C6, C7, C8, Th1	Poor function	Underestimated result

Table III. Analysis of discrepancies between the X-ray myelography result and intraoperative view considering further clinical course

No.	Clinical appearance of the injury	Diagnostic imaging	Intraoperative view	Return of function	Interpretation
1	Upper-middle	Avulsion of C8	No evidence of avulsion	Normal function	False positive result
2	Complete	No evidence of avulsion	Avulsion of C7	Improved function	False negative result
3	Complete	Avulsion of C8, Th1	No evidence of avulsion	Restored function	False positive result
4	Complete	Avulsion of Th1	No evidence of avulsion	Restored function	False positive result
5	Complete	Avulsion of C8	No evidence of avulsion	Poor function	Possible avulsion
6	Complete	Avulsion of C8	Avulsion of C7; C8 in the foramen	Poor function	Possible avulsion
7	Complete	Avulsion of C7, Th1	No evidence of avulsion	Poor function (hand)	Possible avulsion of Th1
8	Complete	Avulsion of C6, Th1	Rupture of the upper trunk; Th1 in the foramen	Restored function	False positive result
9	Complete	Avulsion of C7, C8	Avulsion of C7, C8, Th1	Poor function	Underestimated result
10	Complete	Avulsion of C7, C8, Th1	Avulsion of C7; C8, Th1 in the foramens	Poor function	Possible avulsion
11	Complete	Avulsion of C7, C8, Th1	Avulsion of C6, C7, C8; Th1 in the foramen	Poor function	Discrepancy of levels

dren showed total injuries of the brachial plexus (C5-Th1), while 11 had symptoms of upper-middle lesions of the brachial plexus (C5-C7). Indications for surgical treatment in perinatal brachial plexus palsy include not only preganglionic injuries, but also postganglionic lesions. In this type of injury different degrees of neural element lesions according to Sunderland's scale are observed. The absence of

Table IV. The comparison of efficacy of diagnostic imaging (X-ray myelography and MRI myelography) in relation to intraoperative view

Results of diagnostic imaging	All cases (*n* = 40)	X-ray myelography (XM) (*n* = 20)	MRI myelography (MRI) (*n* = 20)	Statistical significance (XM/MRI)
Consistent	16 (40%)	9 (45%)	7 (35%)	*p* = NS
Without avulsion	3	8	5	
With avulsion	3	1	2	
Inconsistent	24 (60%)	11 (55%)	13 (65%)	*p* = NS
Discrepancy of levels	1	1	0	
False positive results	7	4	3	
False negative results	1	1	0	
Results overestimating injury	2	0	2	
Results underestimating injury	3	1	2	
Possible avulsion based on long-term clinical observation	9	4	5	
Absence of clinical examination	1	0	1	

Table V. Data of patients with suspected avulsion of roots of the lower spinal nerves seen in diagnostic imaging

No.	Avulsion suspected in the diagnostic imaging	Hand function in Al-Qattan scale	Horner syndrome	Improvement in EMG
1	C8, Th1	1	–	None
2	C8, Th1	2	–	Improvement
3	C8, Th1	2	+	Improvement
4	Th1	1	+	Improvement
5	C8, Th1	1	+	None*
6	C8	2	–	Improvement
7	C8	2	+	None
8	Th1	1	–	None*
9	C8, Th1	2	–	None

**temporary improvement in the EMG study, then stationary condition*

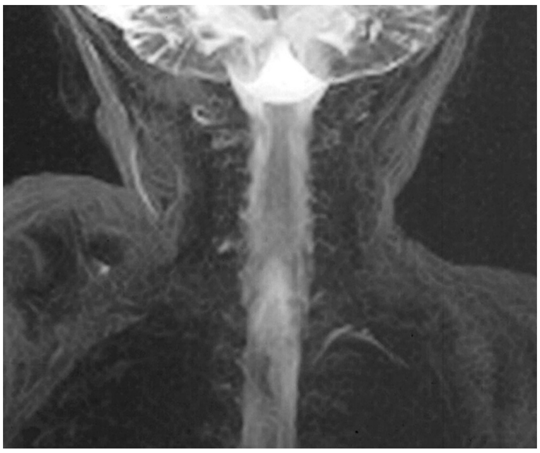

Figure 2. Difficulties in counting levels in small children; MRI image: very small pseudomeningocele laterally to spinal canal (right side) – suspected avulsion of roots of spinal nerve C6

spinal nerve root avulsion in diagnostic images is not a factor excluding the necessity of surgical intervention [10-14].

A main symptom suggesting spinal nerve root avulsion in myelography is a traumatic pseudomeningocele, manifested as an additional enhancement of the signal seen laterally from the dural sac. A pseudomeningocele may be a sign of avulsion of roots of the spinal nerve, but in X-ray myelography it does not constitute a final proof of this injury. Even if the nerve roots' function is maintained, it may be present in 13-18% of cases [12, 14, 15]. Myelographic study involves a risk of side effects. In some cases, aseptic meningitis and short-term convulsions after administration of the contrast agent were observed [11].

The magnetic resonance imaging with myelography option (myelo-MRI) may reveal avulsion with or without presence of traumatic pseudomeningocele [13]. Pseudomeningocele may be an isolated injury or may be associated with an injury to roots of the spinal nerves, including or not their avulsion from the spinal cord [1]. Therefore, when interpreting the results of the imaging studies, one must bear in mind the risk of false positive and false negative results as compared to the intraoperative view [5, 13]. Discrepancies may also concern the level of injury [16]. Difficulties with determination of the level of injury in children may occur due to the variable degree of ossification of vertebrae in small children, which causes level calculation mistakes (Figure 2).

While performing our diagnostic imaging, continuity of roots of the spinal nerves was not assessed, because their contour was not visualised. In interpretation of X-ray myelography and myelo-MRI results, the following indirect symptoms of nerve root avulsion were considered: presence or absence of pseudomeningocele, location of pseudomeningocele suggesting the level of root injury, location of pseudomeningocele in relation to intravertebral foramens and spinal canal, dimension of pseudomeningocele, compression of the dural sac and spinal cord or its absence. The other uncertain myelographic symptoms of nerve root avulsion were deformation or irregular contour of the dural sac, lack of visualisation of nerve roots in the dural sac and intravertebral foramens, and presence of tiny contrast addition which may suggest nerve sheath damage. Analysis of the diagnostic imaging studies performed before the surgery revealed the following discrepancies between their results and the intraoperative view: false positive results, false negative results, discrepancy of levels, results underestimating the injury, and results overestimating the injury. There were also cases in which avulsion of roots of spinal nerve C8 and Th1 was suspected in diagnostic imaging studies, but it was not confirmed intraoperatively. In these children poor improvement of hand function was found as assessed by the Al-Qattan scale [9] (Table V). However, only in 4 out of the 9 children was Horner syndrome observed. If we assume that a complete avulsion of roots of spinal nerves C8 and Th1 is associated with this syndrome, then in the remaining children it was either not avulsion injury or only partial avulsion.

The statistical analysis performed in our material did not reveal significant differences in efficacy of X-ray myelography and MRI myelography in diagnosis of perinatal brachial plexus palsy. The sensitivity and specificity of diagnostic images in our material were similar to those reported in the literature [1, 2, 5, 7]. Analysis of the performed imaging studies revealed their limited usefulness in some respects. In some institutions, there is a tendency to limit indications to preoperative diagnostic imaging, especially CT myelography [10, 17]. Currently, the magnetic resonance imaging technique with high-field devices (1.5 T) applying additional sequences (e.g. FIESTA) allows for very precise assessment of the course of roots of the spinal nerves. As this is a non-invasive study which does not apply radiation, it should be the method of choice in children. One may hope that with further development of MRI techniques, the usefulness of imaging in diagnostics of preganglionic injury of the brachial plexus will increase.

In conclusion, results of diagnostic imaging studies should be included in comprehensive preoperative assessments, but final decisions concerning surgical technique should be based on the clinical and intraoperative view.

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