INTRAOPERATIVE RECTAL AMPULLAR MANOMETRY IN SPINAL CORD CONUS LIPOMA SURGERY IN CHILDREN

K.V. Sysoev, K.A. Samochernykh, W.A. Khachatryan
Almazov National Medical Research Centre, St. Petersburg, Russia

Objective. To assess a potential of using intraoperative rectal ampullar manometry to prevent bladder dysfunction in surgical treatment of the spinal cord conus lipoma.

Material and Methods. The results of surgical treatment of 59 children with lipomas of the spinal cord conus were studied. The presence of urological symptoms (urinary retention or incontinence) was assessed before and after surgery. Intraoperative rectal ampullar manometry was performed in 22 cases with registration of signs of irritation (increased pressure in the rectal ampulla) and depression (decreased pressure in the rectal ampulla) of sacral parasympathetic centers which allowed controlling their proximity and tolerance to the performed manipulations.

Results. Urological symptoms before surgery were detected in 25 (42 %) patients: urinary retention in 7 (28 %), and incontinence in 18 (72 %). Symptoms were significantly more often detected in children older than 3 years ($p < 0.05$). Intraoperatively, a transient decrease in pressure in the rectal ampulla was noted during bipolar coagulation, and a decrease in pressure in the rectal ampulla was noted during ultrasound disintegration. The most pronounced changes in pressure were observed during manipulations along the borderline between the lipoma and the spinal cord in the zone of localization of sacral parasympathetic centers. Persistent profound changes in pressure (>3 mm Hg) have precluded from the total removal of lipoma in all 22 patients; subtotal or partial lipoma removal and release of the tethered spinal cord were achieved in all cases. None of the patients operated on using rectal ampullar manometry presented urinary retention after surgery, these disorders developed in 12 (32 %) children operated on without this procedure ($p < 0.05$).

Conclusion. Paresis or paralysis of the bladder detrusor after removal of the spinal cord conus lipoma may result from direct damage to the parasympathetic sacral centers located at the borderline between the lipoma and the spinal cord. The method of intraoperative rectal ampullar manometry allows protecting the functions of the pelvic organs and determining the safe volume of lipoma resection.

Key Words: spinal cord conus lipoma, lipomyelomeningocele, tethered cord sysndrome, surgical treatment, intraoperative monitoring, rectal manometry.

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Although surgical resection of spinal cord conus lipomas in treatment of children with tethered cord syndrome is one of the conventional approaches typically used by pediatric neurosurgeons, the question regarding the optimal tumor resection volume still remains disputable [1, 2]. The advantages of total lipoma resection are known [3]; however, this type of resection may lead to bladder detrusor paralysis, which is believed to be caused by damage to the functionally important spinal nerve roots and/or the posterior columns of the spinal cord [4–6]. Various methods for intraoperative neurophysiological monitoring have been proposed to prevent these complications, but it was found later that the use of these techniques is limited. Thus, stimulation mapping of spinal nerve roots does not ensure continuous monitoring; evoked potentials (including the bulbocavernosus reflex) are often unobtainable in children and symptomatic patients [6, 7], while the direct intraoperative monitoring of urodynamics is accompanied by substantial technical difficulties, such as the delayed response to stimulation and the need to take into account the changes in abdominal pressure [6, 8, 9].

It is fair to assume that reasonable limitation of tumor resection volume when its maximum resection is possible may reduce the risk of neuro-urological complications. Earlier, intraoperative rectal manometry was used only to detect sacral spinal nerve roots: to do that, a balloon sensor was placed at a level of the anal canal [10–12]. Taking into account that the external and internal anal sphincters are cross-innervated, this procedure later gave way to needle electromyography of the external anal sphincter [13]. Electromyography of the external anal sphincter enabled monitoring of the function of anal and urethral sphincters but not of bladder detrusor [8].

An incentive for performing this study was the integrity of parasympathetic segmental innervation of the rectal ampulla and bladder detrusor, making it possible to use intraoperative rectal ampullar manometry to justify the reduction of safe volume of neurosurgical interventions (subtotal lipoma resec-

tion) in terms of its functional permissibility (prevention of neuro-urological complications).

The objective of this study was to evaluate whether intraoperative rectal ampullar manometry can be used to prevent bladder dysfunction after surgical treatment of spinal cord conus lipoma.

This was a retrospective-prospective single-center group-control study, with sequential parallel comparison design.

Material and Methods

The outcomes of surgeries performed in 59 children with spinal cord conus lipomas at the Pediatric Neurosurgery Department of the A.L. Polenov Russian Neurosurgical Institute (since 2014, a branch of the V.A. Almazov National Medical Research Center) in 2004–2018 were analyzed. Patients with dorsal, transitional, and caudal types of spinal cord conus lipomas (according to the classification suggested by Chapman, 1982) were enrolled. The age distribution of patients is shown in Table 1.

Indication for surgery was the diagnosis of tethered cord syndrome presenting as a combination of sensory loss, weakness and lower extremity deformities, as well as pelvic organ dysfunction.

It was evaluated whether or not the patients had urological symptoms (urinary retention or incontinence) before and after the surgery (Table 2, 3). Only one factor, postoperative changes in the urological status (the emergence of urinary incontinence symptoms), was analyzed in this study.

The microsurgical technique of lipoma resection using an ultrasonic destructor and stimulation mapping of spinal nerve roots was employed in all the cases. Until 2015, either total or subtotal resection was performed (in 37 of 59 analyzed patients). Intraoperative rectal ampullar manometry started to be used since 2015 (in 22 patients).

The compared groups (patients operated on using rectal manometry and without it) were matched in terms of patient number, patients' age distribution, and severity of preoperative urological symptoms.

Manometry procedure. During the study, a Foley catheter balloon equipped with a pre-tested pressure sensor (a Codman microsensor to monitor intracranial pressure) was inserted into the rectal ampulla (Fig. 1a). The depth of balloon catheter implantation was determined according to the coronal MRI data (Fig. 1b). The sensor was calibrated by measuring pressure attained after 5 ml of water had been added to the balloon under atmospheric pressure (~531–535 mm Hg). This parameter was set as the initial pressure level by pressing the «P → 0» button on the instrument panel. Next, normal saline bolus (1 ml) was consecutively administered, and changes in pressure applied to the sensor were recorded. After the implantation, the balloon was also consecutively filled with normal saline to a level when dissociation between the volume/pressure ratio started to be observed under atmospheric pressure (the balloon being placed inside the rectum; Fig. 1c). This was required to ensure an elastic contact between the balloon and the rectal wall.

Next, the deviation of pressure from the value achieved upon elastic contact between the balloon and the rectal wall (pressure at the point of dissociation of the volume/pressure ratio) was taken into account. The detected intraoperative changes in pressure gave grounds to suggest either irritation (increased pressure) or depression (reduced pressure) of the function of sacral parasympathetic centers, which made it possible to estimate their proximity and tolerance to the manipulations being performed. In all cases, the manipulations were stopped once the initial pressure values had been attained. That was how the contractile activity in smooth muscle of the rectal ampulla was continuously monitored.

All the intraoperatively applied methods were approved by the Ethics Committee of the medical institution; a written informed consent was obtained from all the patients enrolled in this study or their legal representatives. The effectiveness of the method was verified by statistical analysis (Pearson χ^2 test and Fisher's exact test; the $p < 0.05$ value was considered statistically significant).

Results and Discussion

Pathological urological symptoms were detected in 25 (42 %) patients: symptoms of urinary retention and incontinence were revealed in 7 (28 %) and 18 (72 %) patients, respectively. Children older than 3 years were significantly more likely to be symptomatic ($p < 0.05$). After the surgery, 12 (32 %) of 37 patients operated on without using rectal manometry presented symptoms of urinary retention. These disorders were detected in none of the patients operated on using rectal ampullar manometry. The intergroup difference was statistically significant ($p < 0.05$). Specifically, the intraoperative changes in rectal pressure were multi-directional for bipolar coagulation and ultrasonic disintegration. In the former case, pressure was reduced, while being increased in the latter case. No correlation between changes in pressure and motor responses from the external anal sphincter were observed (Fig. 2).

The most profound pressure changes were detected upon manipulations at the lipoma–spinal cord boundary, in the zone where the parasympathetic centers of the lateral horns of spinal cord are located. A persistent profound pressure elevation (by > 3 mm Hg) made total lipoma resection infeasible in 22 patients who had undergone rectal ampullar manometry. However, subtotal or partial resection allowed one to perform tethered cord release in all these cases, resulting in a positive outcome in terms of the neurological symptoms.

Fig. 3 illustrates the partial lipoma resection with a good clinical outcome

Table 1
Age distribution of the patients under study

Age, years	Patients, n
<1 year	19
From 1 to 3	13
From 3 to 6	11
From 6 to 10	4
From 10 to 14	9
From 14 to 17	3

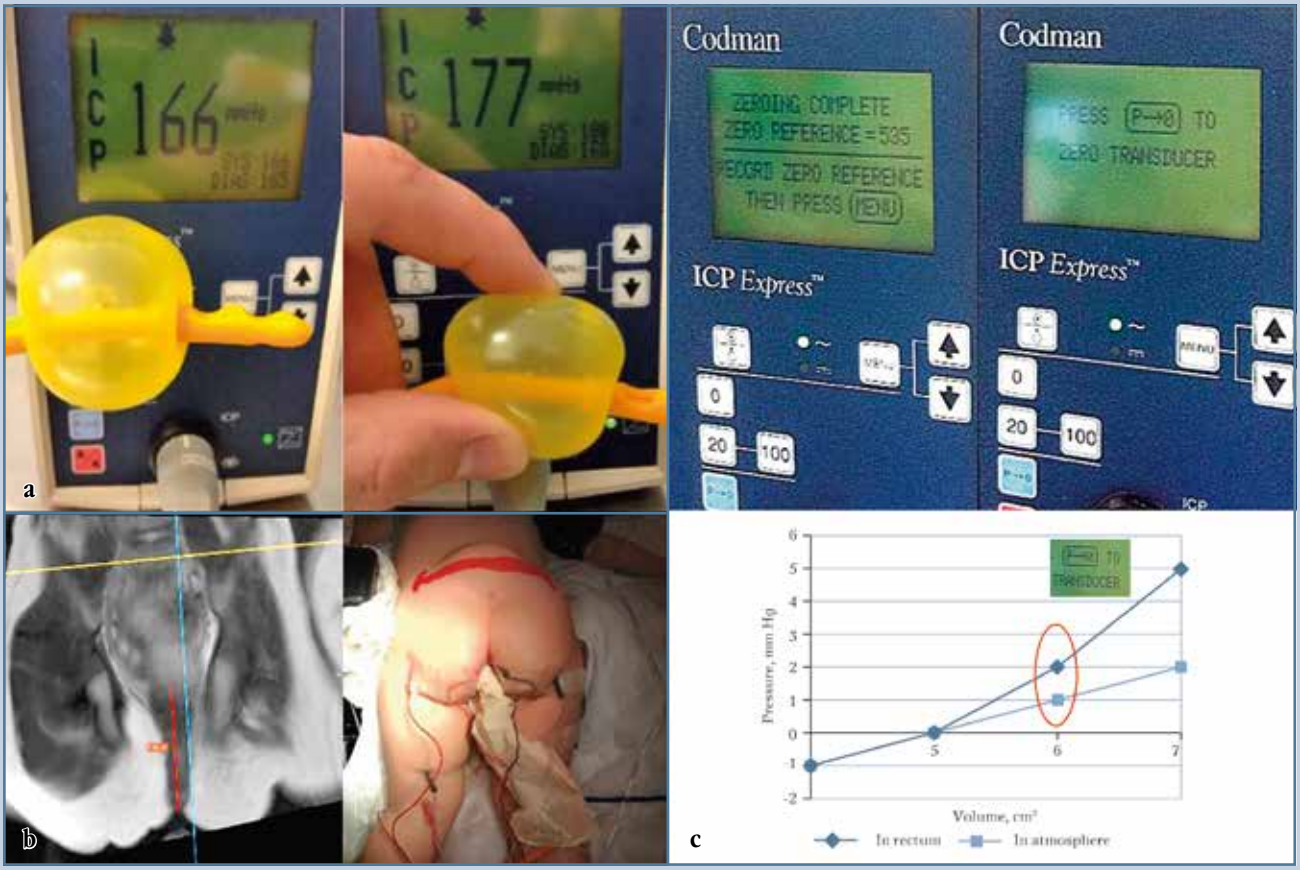

Fig. 1
Pre-testing of the balloon equipped with a pressure sensor **(a)**, measuring the depth of implantation of the balloon catheter according to the coronal MRI data **(b)**, and calibration of the sensor **(c)**: after 5 ml of water had been added, the initial pressure P0 was 535 mm Hg; dissociation of the volume/pressure ratio was achieved after 6 ml of normal saline had been fed into the balloon

achieved. Fig. 4 shows the total lipoma resection accompanied by postoperative urological complications.

None of the patients had wound complications (hematoma or suppuration) that could affect the neurological outcome of the surgery. Specifically, the preoperative urological symptoms in children were not changed after the surgery in both groups (Tables 2, 3).

The problems related to surgical treatment of spinal cord conus lipomas in children have been regularly discussed at international meetings of pediatric neurosurgeons. It is worth mentioning that the microsurgical technique of the surgery has been repeatedly described in the literature, while the development of wound complications is comparable in large case series and is not considered to be a reason for focal neurological complications, including the neurogenic pelvic organ dysfunction [3, 4, 6]. Hence, the question of determining the optimal (radical or partial) resection volume of spinal cord conus lipoma in terms of the functional outcome of a surgery remains the most widely discussed issue. Any new data on the putative mechanisms of the development of postoperative complications have a scientific value.

Although the rate of neurological complications in surgery of the spinal cord conus lipoma is ~5 % [3, 4, 6], it was found that up to 80 % of asymptomatic patients have abnormal bladder dynamics, while postsurgical aggravation in bladder dynamics can be revealed in 20 % of patients [14, 15]. The involuntary activity of the bladder and rectum are known to be governed by the reciprocal cross-regulation mechanism. At the segmental level, this regulation is performed by the lumbar sympathetic and sacral parasympathetic centers. The sympathetic centers are responsible for the contraction of bladder and anal sphincters, ensuring the continence of urine and feces; the parasympathetic centers stimulate the contractile activity of the detrusor and rectal ampulla, thus causing micturition and defecation [3]. We believe that the reason for the most frequent complication (paralysis/paresis of the bladder detrusor) is the dysembryogenetic features of formation of spinal cord conus lipomas, since tumor invasion of

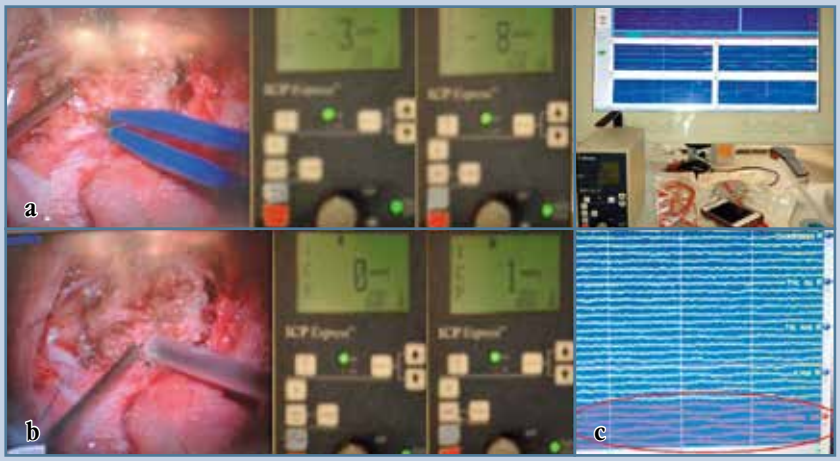

Fig. 2
Pressure measurements upon coagulation **(a)** and ultrasonic disintegration **(b)**; needle electromyography detected no motor responses from the external anal sphincter **(c)**

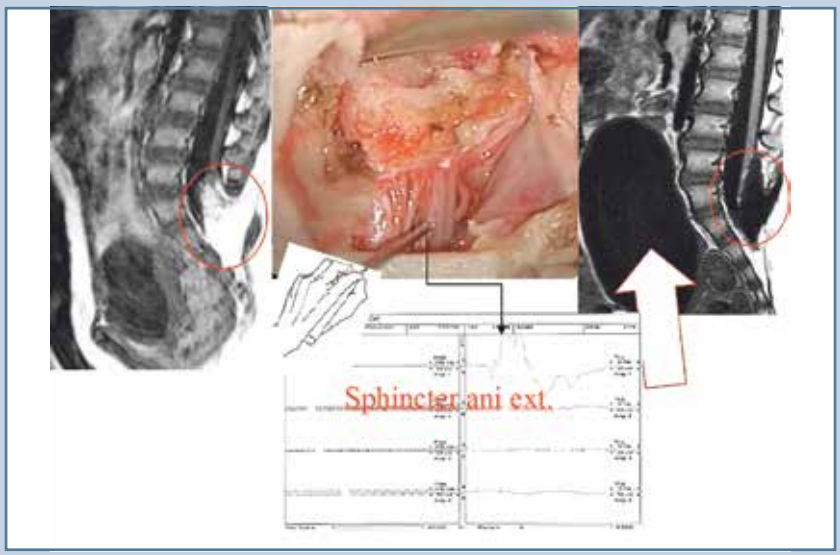

Fig. 4
A 1.5-year-old patient having moderate motor deficit without urological symptoms: total lipoma resection under guidance of intraoperative stimulation mapping of sacral roots (the central image); postsurgical paralysis of the detrusor

the opened neural placode occurs at the level of sacral parasympathetic centers that regulate the pelvic organ function [5, 16, 17]. In our opinion, paralysis/paresis of bladder detrusor after resection of spinal cord conus lipoma may result from direct damage to the centers residing in the lateral horns of the spinal cord rather than spinal nerve roots or the posterior columns of the spinal cord, as it was believed previously [6].

Rectal ampullar manometry allowed one to detect signs of irritation or depression of sacral parasympathetic

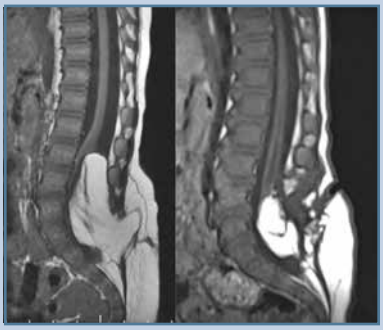

Fig. 3
A 2-month-old patient with foot deformity having no urological symptoms: partial lipoma resection under guidance of rectal manometry and tethered cord release. No symptoms were observed within 4 years after the surgery

centers during resection of spinal cord conus lipoma, which presented as an elevation or reduction of pressure applied to the balloon catheter by the rectal wall. Hence, continuous intraoperative monitoring of the function of sacral parasympathetic centers prevented their damage as the surgeons did not perform total lipoma resection. Due to its technical simplicity, rectal ampullar manometry can be considered an efficient method for intraoperative monitoring of the pelvic functions during microsurgical resection of spinal cord conus lipomas in children, thus allowing neurosurgeons to safely perform surgeries without using the unnecessary procedures and expensive monitoring equipment.

Conclusions

Paresis or paralysis of the bladder detrusor after resection of the spinal cord conus lipoma can result from direct damage to the sacral parasympathetic centers located on the spinal cord–lipoma boundary. Their functions can be monitored intraoperatively using rectal ampullar manometry. This method can be used to preserve the bladder and rectal function and to determine the safe tumor resection volume.

Table 2
Characteristics of patients operated on without using rectal ampullar manometry

Patients	Age, months	Preoperatively	Postoperatively
1st	1	I	I
2nd	1	I	I
3rd	3	N	N
4th	3	N	R
5th	5	N	N
6th	5	N	N
7th	6	N	N
8th	7	N	R
9th	8	I	I
10th	8	N	R
11th	10	N	R
12th	10	N	R
13th	16	N	N
14th	23	N	R
15th	24	N	R
16th	28	I	R
17th	31	N	R
18th	36	I	R
19th	36	N	R
20th	39	R	R
21th	47	N	R
22th	48	I	I
23th	48	N	N
24th	50	N	N
25th	72	I	I
26th	72	I	R
27th	72	I	I
28th	84	N	N
29th	84	N	R
30th	120	I	I
31th	120	R	R
32th	120	N	I
33th	120	N	N
34th	132	I	I
35th	144	N	N
36th	156	R	R
37th	216	R	R

N — without urological symptoms; R — urinary retention; I — urinary incontinence.

The risk of these complications can be reduced only if the spinal surgeons reasonably stop performing total lipoma resection. The use of intraoperative rectal ampullar manometry during these surgeries allows one to intraoperatively control safe volume of lipoma resection, thus preventing postoperative bladder dysfunction. The reasonably safe extent of lipoma resection in this case ensures a better functional outcome than total lipoma resection does.

Table 3
Characteristics of patients operated on using rectal ampullar manometry

Patients	Age, months	Preoperatively	Postoperatively
1st	2	N	N
2nd	2	N	N
3rd	4	I	I
4th	4	N	N
5th	5	N	N
6th	8	N	N
7th	8	N	N
8th	14	N	N
9th	15	R	R
10th	16	N	N
11th	19	N	N
12th	33	R	N
13th	33	N	N
14th	45	N	N
15th	48	I	I
16th	48	I	I
17th	96	I	I
18th	108	I	I
19th	120	I	I
20th	156	R	R
21th	180	I	I
22th	204	N	N

N — without urological symptoms; R — urinary retention; I — urinary incontinence.

Limitations of the study

1. This study did not focus on such complications of resection of spinal cord conus lipomas as defecation disorders. Constipation is similar to urinary retention but is not as clinically important and is occult more often. Nevertheless, the similar pathogenesis of these conditions gives grounds for assuming that the proposed method will reduce the risk of these complications as well.

2. The study was not aimed at evaluating the effectiveness of rehabilitation or the long-term outcomes of neuro-urological complications after resection of spinal cord conus lipomas.

3. The multidirectional nature of changes in rectal pressure in response to the manipulations performed using a bipolar coagulator and an ultrasonic destructor are of undoubted interest for further research in the field of functional spinal neurosurgery. In this study, we have only outlined these differences.

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Address correspondence to:
Sysoev Kirill Vladimirovich
Almazov National Medical Research Centre
2 Akkuratova street, St. Petersburg, 197341, Russia,
sysoev.rnsi@mail.ru

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Kirill Vladimirovich Sysoev, MD, PhD, senior researcher, Almazov National Medical Research Centre, 2 Akkuratova street, St. Petersburg, 197341, Russia, ORCID: 0000-0002-6868-1186, sysoev.rnsi@mail.ru;
Konstantin Aleksandrovich Samochernykh, DMSc, leading researcher, Almazov National Medical Research Centre, 2 Akkuratova street, St. Petersburg, 197341, Russia, ORCID: 0000-0001-5295-4912, neurobaby12@gmail.com;
William Aramovich Khachatryan, DMSc, Prof., chief researcher, Almazov National Medical Research Centre, 2 Akkuratova street, St. Petersburg, 197341, Russia, ORCID: 0000-0002-1635-6621, wakhns@gmail.com.