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REVIEW ARTICLE

A review of current treatment for lumbar disc herniation in children and adolescents

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Abstract Lumbar disc herniation (LDH) is a common disorder among adults with degenerated lumbar intervertebral discs. However, its occurrence in childhood and adolescence is much less frequent mostly because children and adolescents tend to have a healthier lumbar spine as compared with adults. This difference indicates that children and adolescents are far from being just little adults. Over the years, there have constantly been published studies concerning this entity where the findings suggested that pediatric LDH is, in many ways, different from that in adults. To date, the prevalence, the etiological and the diagnostic features of pediatric LDH have been fully described in the literature whereas the characteristics regarding to the treatment is yet to be reviewed in details. The aim of the present review is to provide a collective opinion on the treatment of pediatric LDH as well as its outcome. It reviewed the relevant information available in the literature and compared the results among and within various treatments. It was found that pediatric patients responded less favorably to conservative treatment as compared with adults. In addition, the outcome of surgery remained to be satisfactory for at least 10 years after the initial operation, even though it appeared to deteriorate slightly. To the best of our knowledge, this is the first literature review focusing on the treatment of pediatric LDH.

Keywords Child · Adolescent · Therapeutics · Treatment outcome · Intervertebral disc displacement · Lumbar disc herniation

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Introduction

It has long been noticed that lumbar disc herniation (LDH) affects not only adults but also children and adolescents (pediatric LDH). Unique physiological natures of children and adolescents endow pediatric LDH with some distinctive features. However, almost all attention was given to adult LDH with pediatric LDH remaining partially understood. Over the years, the number of studies in this regard was on a rise, which led to an ever increasing understanding of this entity. Yet to the present date, it has not been fully reviewed as to the treatments available for pediatric LDH and the effect of each treatment. This study is to answer these questions by reviewing all the related studies available in the literature. To the best of our knowledge, it is the most comprehensive review on this issue so far.

Materials and methods

Searching strategy

Literature search was performed in electronic database PUBMED and EMBASE using MeSH terminologies (child, adolescent, therapeutics, treatment outcome, intervertebral disc displacement) and key words (child, adolescent, LDH), respectively. No limitation was applied during the search. All relevant articles were initially selected by title and abstract.

Inclusion criteria

Articles with relevant information concerning LDH in children and/or adolescents were included. Additional references with relevant information were identified from these articles and included in the review as well.

All articles were scrutinized for details concerning assessment of clinical outcome. Good and/or excellent outcome was rated in majority of case series when the outcome met at least one of the following criterions: (1) no or minor pain remains, (2) patients return to normal daily activities, (3) patients were satisfied with the outcome of the treatment. These series were included in the review. In each series, 'Success Rate' was defined as the rate of cases with good and/or excellent outcome as rated above.

Exclusion criteria

Cases series without detailed description of outcome assessment were excluded. Cases series containing patients aged over 21 years were also excluded as previous studies had shown that the growth of body was almost completed by the end of the second decade of life [1].

Searching results

In total, there were 55 case series and 8 case reports including 1,963 cases of intradiscally or surgically treated pediatric LDH initially obtained from the literature search. Eleven of the series with 299 cases were subsequently excluded based on the exclusion criteria (9 series for lack of detailed description, 2 series for patients' average age over 20 years). At last, 44 series and 8 case reports with 1,664 cases being included in the review. Included articles dated from 1945 to 2008.

General features

Prevalence

Lumbar disc herniation is a common disorder among adults, with reported lifetime occurrence as high as 40% [2]. Although the true frequency of this condition in children and adolescents is not precisely defined, it is generally believed to be much lower than that in adults. It was reported that pediatric patients constitute only 0.5–6.8% of all patients hospitalized for LDH [3–5], which was much lower than the estimated percentage of children and adolescents population (27%) [6]. Zitting et al. [7] carried out an epidemiologic study aiming at estimating the true prevalence. They followed up 12,058 Finnish babies (all the babies born in the northern part of the country in 1966) from birth until 28 years of age. Their results showed that none of their subjects was hospitalized with confirmed LDH until the age of 15 years, while this figure increased to the range of 0.1–0.2% when the subjects were 20 years old. From this point onwards, the prevalence began to rise dramatically. By the age of 28 years, 9.5% of males and 4.2% of females were admitted to hospital with a diagnosis of LDH, respectively.

Causes

Several factors have been identified as the potential causes of pediatric LDH. Trauma (mostly sport-related or self-reported injury, i.e. heavy lifting, extreme flexion–extension, fall, etc.) is commonly considered as the most likely cause because as many as 30–60% of children and adolescents with symptomatic LDH have a history of trauma before the onset of pain [8–13]. This is in contrast to adult patients who usually do not have any traumatic experiences before the symptoms occur. However, more recent studies suggest that instead of being a primary contributory factor, trauma is likely to be an inciting event in the exacerbation of the pre-existing lesion in the discs, e.g. micro-damage, degenerative changes, etc. [12, 14, 15]. The second generally recognized cause is genetic factor. Studies have shown that between 13 and 57% of adolescents with LDH have a first-degree relative with the same disorder [16–18]. Vertebral anomalies such as scoliosis, transitional vertebra (lumbarisation and sacralisation) et al. are known to be associated with LDH in children and adolescents [8, 19–21], even though their influence has not been quantified. There were also a few studies demonstrating the association of epiphyseal ring separation with pediatric LDH, with reported concurrent rate up to 40% [12, 22, 23]. Yet no difference in clinical outcome was detected between patients with or without slipped epiphysis [24].

Clinical characteristics

Clinical presentations of pediatric LDH are generally similar to those observed in adults [12, 15]. One distinctive feature is that up to 90% of patients have a positive straight-leg raising test [10, 25], which can be explained by the finding that children and adolescents tend to have a greater nerve root tension than adults [26]. However, children and adolescents are less often seen with neurological symptoms such as numbness and weakness [5, 17, 27].

Treatment

Homogeneity and heterogeneity of included studies

Included series were assessed for the level of evidence according to the guidelines proposed by Centre of Evidence Based Medicine (CEBM) [28]. All series were rated grade 4 level of evidence. All cases included in the review were under 21 years old. Diagnosis of LDH in the series was all made based on combined evidences of clinical symptoms, physical examination and imaging findings. For each surgical treatment modality, standard surgical procedure was followed in all series.

Included series were heterogeneous in terms of treatment modality, follow-up duration and outcome (assessed by success rate), which were determined as the variables of the present review. Series concerning different treatment modalities were categorized and discussed separately. For each treatment modality, a 5-year follow-up rule was used to category the series into short-term (<5 years), mid-term (5–10 years) and long-term (>10 years) follow-up studies, and outcome of treatment is assessed individually when possible.

Conservative treatment

Conservative treatment of pediatric LDH consists of bed rest, analgesic and anti-inflammatory agents, physical therapy and limitation of physical activities [29]. At the onset or acute phase of the disease, 1–2 weeks' bed rest can be recommended for patients with severe pain [18, 30] followed by the use of a brace for a few weeks afterwards [17]. Non-steroidal anti-inflammatory drugs are always prescribed as an adjunct therapy to bed rest. There were also reports of successful results from the use of epidural steroid injections as a part of conservative treatments for pediatric LDH [29, 31]. A search of the literature indicates that the short to long-term success rate of conservative treatment for pediatric LDH without neurological deficits varied from 25 to 50% [16, 18, 32]. Kurth et al. [32] compared outcome of conservative treatment with surgical treatment for 33 pediatric patients (18 conservatively and 15 surgically treated cases) with a follow-up of 5.4 years, and found no significance between the two groups. DeLuca et al. [18], however, found that surgical treatment lead to a significant better outcome than conservative treatment by carrying out a similar study on 31 pediatric patients (8 conservative, 23 surgical) with a 6-year follow-up. Regardless of the controversy, it has been widely agreed by most authors that conservative treatment is not as effective for pediatric LDH as it is for adults [11, 14, 27, 33, 34].

There may be several explanations for the disappointing result of conservative treatment: (1) the herniated nucleus pulposus of children, as compared with adults, is less degenerated, more hydrated, soft and viscous [11, 14, 35]; it does not dry up and resorb like a degenerated adult disc might [29]; (2) pediatric LDH is often associated with trauma where the annulus fibrosus could be severely ruptured [36]; (3) the epiphyseal cartilage of the vertebral body in children and adolescents is not fully fused, hence severe trauma could rupture the epiphyseal ring forming a large implastic mass along with the herniated disc [37]; (4) children and adolescents are active and less likely to comply to strict bed rest.

Nevertheless, conservative treatment is still generally recommended as the first-line treatment for LDH in children and adolescents without neurological deficits [16, 27, 29, 38, 39]. This may be due to the concern that a growing spine is vulnerable to surgical trauma and iatrogenic deformities can develop after surgical intervention in children and adolescents [40, 41].

Intradiscal therapy

Although there are various forms of intradiscal therapy available for adult LDH, similar reports on children and adolescents are comparatively sparse. According to the literature, chemonucleolysis was the only form of intradiscal therapy reported being used on children and adolescents. Although FDA approval for chymopapain use in humans has long been withdrawn, it is still being manufactured and in clinical use in Korea, Canada, Australia, UK and three states in the US [42]. In comparison with surgery, chemonucleolysis is advantageous in that it is associated with less trauma and post-operative adhesion, shorter hospital stay, earlier remobilization and lower cost. In 1985, Lorenz and McCulloch [43] conducted a study where 54 children and adolescents with LDH were primarily treated with chemonucleolysis; those who failed the treatment were then treated with surgery. After a follow-up of 4.5 years, they found that outcome of primary chemonucleolysis followed by surgery was not significantly different from that of surgery alone. This finding was supported by the study of Bradbury et al. [44] who applied the same procedure to 42 cases with a 8.5-years' follow-up leading to a similar result. Similar finding was also reported on adult patients [45]. The authors recommended chemonucleolysis should be attempted before surgery for children and adolescents who did not respond to conservative treatment. After summarizing related studies and 65 cases of pediatric LDH from his own experience, Kuh et al. [41] proposed indications for chemonucleolysis as following: (1) patients with leg pain more severe than back pain, (2) severely limited straight-leg raising test, (3) CT confirmed soft disc herniation. As far as the outcome was concerned, chemonucleolysis was associated with 80–89% short-term success rate [41, 43]. This figure dropped to 64% in a mid-term follow-up study though [44]. Moreover, it was estimated that 11–26% of cases could fail the chemonucleolysis and subsequently needed a surgery (Table 1).

One case of anaphylactic reaction after chemonucleolysis was reported by Lorenz and McCulloch [43]; the patient was treated successfully at last. The most common symptom after injection is increased back pain, but it can be controlled with medication [43]. Leakage of contrast

Table 1 Clinical outcome of chemonucleolysis as reported in the literature

Study	Year	No. patients	Age[a] (years)	Follow-up period[a] (years)	Success rate (%)	Re-op rate (%)
Kuh et al. [41]	2005	65	18.4 (10–20)	N/A (1–4)	89	11
Bradbury et al. [44]	1996	42	N/A (13–19)	8.5 (N/A)	64	26
Lorenz and McCulloch [43]	1985	54	N/A (13–19)	4.5 (2–12)	80	20

N/A Not available

[a] The values are given as the means, with the ranges in the parenthesis

medium during injection appears to have no effect on clinical outcome [45]. Disadvantages of chemonucleolysis are that it has a limited capability of nuclear removal and uncertain nerve root decompression effect as compared with surgery, thus it is not suitable for severely extruded discs [41].

Surgical treatment

Indications

Indications for surgical intervention on pediatric LDH appear to be generally agreed in the literature. These include: (1) severe pain refractory to 4–6 weeks of conservative treatment (2) disabling pain affecting one's daily activities, (3) cauda equina syndrome, (4) progressive neurological deficits, (5) associating spinal deformities [8, 20, 29, 46].

Modalities and outcome

Like adults, modalities of surgical treatment for pediatric LDH consist of percutaneous endoscopic discectomy (PED, also known as microendoscopic discectomy) and open discectomy including microsurgical discectomy or microdiscectomy (MD), discectomy with laminotomy or laminectomy and spinal fusion.

Percutaneous endoscopic discectomy With the increasing use of endoscopic surgical techniques in spinal surgery, PED was introduced to the treatment of pediatric LDH [47]. Two relevant articles published by Mayer et al. [47] (4 cases) and Lee et al. [48] (46 cases) were obtained from literature search. PED was associated with short-term success rate of 91.3 and 100% respectively, without complications such as leakage of CSF, nerve root injury, interspace infection, etc. The long-term follow-up is yet to be reported. Their recommended indications of PED for pediatric LDH include: (1) failure of 6 weeks of conservative treatment; (2) a comparatively intact disc; (3) subligamentously protruded or extruded disc. The minimally invasive nature of PED means less surgical trauma and shorter hospital stay. Its success, however, requires a correct selection of patients and the surgeon being able to master the surgical procedure.

Open discectomy Discectomy remains the mostly used surgical procedure for LDH in children and adolescents as well as in adults. It is generally agreed in the literature that posterior discectomy with partial laminotomy is indicated for posterolateral disc herniation, whereas semilaminotomy or laminectomy is required in cases of central disc herniation. There were also reports of successful use of extraperitoneal anterolateral discectomy on centrally protruded disc [49, 50]. More recently, MD has also been used for the treatment of pediatric LDH [27, 35, 37, 41, 46] and associated with good result. The present review found five published series with clinical outcome obtained from 143 MD cases. The short-term success rate ranged from 98 to 100% while the mid and long-term success rate dropped to 92 and 85% (Table 2), respectively.

Table 2 Clinical outcome of MD as reported in the literature

Study	Year	No. patients	Age[a] (years)	Follow-up period[a] (years)	Success rate (%)
Ozgen et al. [27]	2007	17	N/A (13–17)	5 (N/A)	100
Kuh et al. [41]	2005	94	18.4 (10–20)	N/A (1–4)	98
Villarejo-Ortega et al. [35]	2003	10	N/A (<20)	N/A (2–5)	100
Luukkonen et al. [46]	1997	12	14.3 (N/A)	6 (N/A)	92
Silvers et al. [37]	1994	10	N/A (<21)	10.5 (N/A)	85

N/A Not available

[a] The values are given as the means, with the ranges in the parenthesis

In comparison with PED, discectomy is associated with more sufficient decompression. However, extensive dissection of soft tissues can also result in post-operative back pain. Since children and adolescents have a greater nerve root tension than adults, excessive root manipulation during discectomy is more likely to cause nerve damage [26]. This flaw is intended to be compensated in MD. With a small incision and the use of an operating microscopy the risk of excessive nerve root manipulation and the likelihood of overlooking sequestered disc material can be reduced.

One crucial question regarding discectomy is how much disc material should be removed? A discectomy with insufficient nucleus removal is likely to fail [29]. Excessive nucleus removal, however, can lead to stenosing changes at operated disc level and degenerative changes at adjacent disc levels [46]. Ishihara et al. [49] believe that all degenerated nucleus and ruptured annulus should be removed while the remaining disc structures being preserved. For children and adolescents, it is especially important to maintain the integrity of the inner part of the annulus where the proteoglycan synthesis is the most active [51]. Ishihara's et al. [49] study showed that performing a discectomy while leaving the inner annulus intact could lead to regeneration of the intervertebral disc.

The present review summarized the short-term outcome of discectomy reported in 22 published articles, the number of cases involved was 798 (Table 3). The mid and long-term outcome was collected from 15 and 9 articles with 442 and 398 cases included, respectively (Tables 4, 5).

Short, mid and long-term outcomes were assessed separately (Tables 3, 4, 5) by pooling the success rates collected from different series. Weighted mean was used to preclude the effect of the sample size difference among the studies on the overall mean success rate.

Table 3 indicates that discectomy was associated with good short-term outcome, with the success rate ranging from 79 to 100% (weighted mean 94.9%). However, according to Table 4, more series with lower success rates were reported at mid-term follow-up. Reported success rates had a wider range from 65 to 100%, the weighted mean dropped to 86.8%. Continuous decrease in success rate was seen among the long-term follow-up series (Table 5) where the weighted mean of success rates decreased to 81.8% even though the range was still between 67 and 100%. A horizontal comparison between

Table 3 Short-term outcome of discectomy as reported in the literature

Study	Year	No. patients	Age[a] (years)	Follow-up period[a] (years)	Success rate (%)
Kumar et al. [14]	2007	23	N/A (<20)	Immediately post-op	92
Pietila et al. [52]	2001	74	N/A (<17)	0.8 (N/A)	95
Parisini et al. [15]	2001	129	16.2 (9–18)	Immediately post-op	95
Papagelopoulos et al. [12]	1998	72	16 (N/A)	N/A (<1.0)	93
Luukkonen et al. [46]	1997	12	N/A (<15)	0.5 (N/A)	100
Shillito [11]	1996	20	N/A (10–15)	N/A (<3)	100
Kurth et al. [32]	1996	15	N/A (<20)	Immediately post-op	93
Silvers et al. [37]	1994	15	N/A (<21)	0.3 (N/A)	100
Ferrante et al. [53]	1992	48	17.4 (13–20)	0.3 (N/A)	95.8
Ghabrial and Tarrant [54]	1989	26	N/A (13–18)	1 (N/A)	88
Plangger et al. [55]	1989	11	N/A (<19)	Immediately post-op	100
Ebersold et al. [21]	1987	60	15 (11–16)	0.75 (N/A)	95
Zucker et al. [1]	1987	61	N/A (10–18)	N/A (0.3–10)	95
Epstein et al. [25]	1984	25	N/A (12–19)	N/A (2–4)	96
DeOrio and Bianco [20]	1982	50	15 (11–16)	Immediately post-op	94
Garrido et al. [5]	1978	30	N/A (10–18)	N/A (0.5–5)	93
Beks and ter Weeme [13]	1975	43	N/A (11–18)	2 (N/A)	100
Borgesen and Vang [56]	1974	24	N/A (11–19)	4.2 (N/A)	79
Bulos [33]	1973	5	N/A (14–19)	N/A (1–3.5)	100
Rugtveit [57]	1966	7	N/A (11–17)	4.9 (N/A)	100
Epstein et al. [3]	1964	10	N/A (15–19)	N/A (<4)	100
O'Connell [58]	1960	38	N/A (15–20)	Immediately post-op	100

N/A Not available

[a] The values are given as the means, with the ranges in the parenthesis

Table 4 Mid-term outcome of discectomy as reported in the literature

Study	Year	No. patients	Age[a] (years)	Follow-up period[a] (years)	Success rate (%)	Re-op rate (%)
Smorgick et al. [24]	2006	26	14.6 (12–17)	8.9 (3–21)	65	15
Chen et al. [59]	2004	28	N/A (14–18)	6.1 (N/A)	93	3.5
Durham et al. [9]	2000	29	N/A (<17)	8.5 (0.3–30.5)	83	24
Luukkonen et al. [46]	1997	12	14.3 (<15)	6 (3.5–9.1)	90	N/A
Ishihara et al. [49]	1997	8	N/A (<16)	9 (5–12)	100	N/A
Kurth et al. [32]	1996	15	N/A (<20)	5.4 (0.8–10)	87	N/A
DeLuca et al. [18]	1994	23	16 (16–20)	6 (2–17)	91	4
Gennuso et al. [10]	1992	77	16 (10–18)	8.2 (N/A)	97	3
Miralles et al. [60]	1990	9	N/A (12–19)	N/A (6–15)	100	0
Zucker et al. [1]	1987	61	N/A (10–18)	N/A (0.3–10)	95	3
Kamel and Rosman [34]	1984	10	14.2 (11–16)	5 (N/A)	90	N/A
Clarke and Cleak [17]	1983	18	N/A (8–19)	6.8 (2–14)	78	4
Blaauw et al. [61]	1981	80	N/A (8–19)	5.5 (N/A)	75	N/A
Russwurm et al. [62]	1978	37	N/A (10–18)	5.5 (N/A)	84	3
O'Connell [58]	1960	9	N/A (15–20)	N/A (5–10)	91	N/A

N/A Not available

[a] The values are given as the means, with the ranges in the parenthesis

Table 5 Long-term outcome of discectomy as reported in the literature

Study	Year	No. patients	Age[a] (years)	Follow-up period[a] (years)	Success rate (%)	Re-op rate (%)
Parisini et al. [15]	2001	98	16.2 (9–18)	12.4 (N/A)	87	10
Papagelopoulos et al. [12]	1998	72	N/A (<16)	27.8 (12–45)	67	28
Poussa et al. [63]	1997	18	N/A (11–17)	10 (N/A)	100	N/A
Shillito [11]	1996	17	N/A (<15)	N/A (20–36)	88	12
Silvers et al. [37]	1994	15	N/A (<21)	10.5 (N/A)	85	N/A
Ebersold et al. [21]	1987	60	15 (11–16)	18 (2.5–34)	77	22
DeOrio and Bianco [20]	1982	50	15 (11–16)	19 (5–30)	73.5	25
Kurihara and Kataoka [8]	1980	26	16.2 (9–19)	10.3 (5–17)	96	4
Fisher and Saunders [64]	1981	43	N/A (<21)	N/A (4–30)	91	9

N/A Not available

[a] The values are given as the means, with the ranges in the parenthesis

Tables 4 and 5 indicated that mid-term follow-up cases were associated with lower re-operation rate (weighted mean 6.1%) as compared with long-term follow-up cases (weighted mean 17.1%). Papagelopoulos et al. [12] calculated the re-operation rate of 72 surgically treated cases using Survivorship Analysis and suggested that the probability that a patient would not need a re-operation was 80% at 10 years and 74% at 20 years after the initial operation.

There were six long-term studies in Table 5 also containing short-term follow-up information from 312 pediatric patients, which allowed a longitudinal comparison of short-term with long-term outcome to be carried out. The result showed that long-term success rate was lower than short-term in each of the studies (Table 6) with the figure decreasing from 93 to 100% (weighed means 95%) to 67–88% (weighed means 78.3%). This figure, however, is still markedly higher than that of adults [65].

Interestingly, a comparison between Tables 2 and 3 indicates that MD and discectomy appear to be associated with equally good clinical outcome. Similar finding was also made by other authors [8, 14, 47].

Fusion There have been a few reports in the literature concerning the use of spinal fusion on pediatric LDH (Table 7) [4, 20, 41, 49, 66]. The aim of fusion is to relieve

Table 6 Comparison of short-term outcome with long-term outcome as reported in the literature

Study	Year	Age[a] (years)	No. patients		Follow-up period[a] (years)		Success rate (%)	
			Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Parisini et al. [15]	2001	16.2 (9–18)	129	98	Immediately post-op	12.4 (N/A)	95	87
Papagelopoulos et al. [12]	1998	N/A (<16)	72		<1	27.7 (12–45)	93	67
Shillito [11]	1996	N/A (<15)	20	17	<3	N/A (20–36)	100	88
Silvers et al. [37]	1994	N/A (<21)	15		0.3	10.5 (N/A)	100	85
Ebersold et al. [21]	1987	15 (11–16)	60		2.5	18 (2.5–34)	95	77
DeOrio and Bianco [20]	1982	15 (11–16)	50		Immediately post-op	19 (5–30)	94	73.5

N/A Not available

[a] The values are given as the means, with the ranges in the parenthesis

Table 7 Clinical outcome of discectomy with fusion as reported in the literature

Study	Year	No. patients	Age[a] (years)	Follow-up period[a] (years)	Success rate (%)
Kuh et al. [41]	2005	26	18.4 (10–20)	N/A (1–4)	94
Ebersold et al. [21]	1987	14	15 (11–16)	Immediately post-op	86
Leong et al. [50]	1982	20	N/A (<20)	4.3 (N/A)	95
Grobler et al. [4]	1979	23	N/A (14–20)	5.3 (N/A)	89

N/A Not available

[a] The values are given as the means, with the ranges in the parenthesis

symptoms by restoring stability. However, the majority of the authors agreed that fusion should not be performed routinely for pediatric LDH [8, 12, 19, 21, 34, 37]. The mostly accepted indications for spinal fusion are limited to: (1) disc herniation with spondylolisthesis or clear indications of instability, (2) multiple level laminectomy, (3) incompetence of the facet joints due to either congenital, degenerative or iatrogenic causes. It was demonstrated in several studies that spinal fusion did not improve outcome or decrease the recurrence rate of disk herniation significantly but at a cost of increasing operative time, blood loss and cost [8, 12, 19, 34].

Post-operative complications

Early post-operative complications found in pediatric patients include wound hematoma (1–4%) and delayed wound healing (3%) [8, 12, 20]. Post-operative infection, e.g. wound infection and discitis secondary to lumbar spine surgery is rare in children and adolescents with only few cases being reported in the literature [15, 46, 67].

Although there have been reports of narrowing of disc space, foraminal stenosis and adjacent disc degeneration from few months to several years after discectomy, the clinical outcome was not affected accordingly [46, 49, 60, 63]. This is consistent with the findings from adults [68]. It was also found that multiple level laminectomy, particular at thoracolumbar region, and damage to the facet joints could result in spinal instability and deformity [69]. Furthermore, Herring and Asher [70] showed that 5–10% of the pediatric patients could have a recurrent disc herniation at the operated level.

LDH in children younger than 10 years

Noticeably, the case series obtained in this review consisted almost exclusively of children and adolescents older than 10 years. In fact, the literature search disclosed only eight case reports (9 cases) of LDH in children younger than 10 years. The scarcity of publications on this issue reflects Zitting's as well as other authors' finding that LDH rarely occurs to children younger than 12 years [7, 15, 24].

Table 8 gives the details of these reported cases. Similar to older children and adolescents, trauma also appears to be closely related to LDH in younger children, with at least 4/9 cases presenting symptoms after traumatic experience. Clinical manifestations observed from this group of patients were generally similar to that of older children and adolescents, except that clinical signs were more likely to be neglected as younger children tended to lack co-operation during examinations. Moreover, for a young child presenting with low back pain and neurological disturbance of lower limbs, extra attentions were needed on differential

Table 8 Case reports of LDH in children and adolescents under 10 years of age

Study	Year	No. patients	Age (years)	Onset after trauma	Diagnosis	Standard discectomy	Follow-up period	Free from symptoms
Benifla et al. [71]	2008	1	1.1	N/A	N/A	Y	N/A	N/A
Martinez-Lage et al. [72]	2003	1	6	Y	Symptoms + physical exam + X-ray + MRI	Y	3 months	Y
Revuelta et al. [40]	2000	1	2.3	Y	Symptoms + physical exam + X-ray + MRI	Y	7 years	Y
Ishihara et al. [49]	1997	1	9	Y	Symptoms + physical exam + myelography	Y	12 years	Y
Bartolozzi et al. [73]	1989	2	<10	N/A	Symptoms + physical exam + X-ray + CT	N/A	Long-term	Y
Kurihara and Kataoka [8]	1980	1	9	N/A	N/A	Y	6 years	Y
MacGee [74]	1968	1	9	N/A	N/A	N/A	1 year	Y
King [75]	1959	1	3.8	Y	N/A	N/A	2 weeks	Y

N/A Not available, *Y* yes

diagnosis such as neoplasm, infection and deformities [71]. According to Table 8, at least 5/9 cases were diagnosed based on not only the symptoms and physical examination, but imaging studies. Although the corresponding information was not obtained for the remaining cases, they all appeared to respond well to surgical treatment for LDH.

Table 8 shows that all cases were treated with discectomy after the conservative treatment failed. Surgical treatment was found to be associated with excellent outcome in 8/9 cases, with short-term (3/9 cases), mid-term (2/9 cases) as well as long-term follow-up (3/9 cases, follow-up period was not clearly defined in 2/3 cases). These reports covered children of various ages from 1 to 9 years. The results were in great consistency. According to these reports, LDH does occur to children younger than 10 years and surgical treatment can relieve the symptoms effectively. Information provided in this section is valuable in that it makes the review covering children and adolescents of all age.

Conclusions

Pediatric LDH is a rare entity leading to hospitalization of approximately 0.1–0.2% of children and adolescents. Diagnosis of pediatric LDH is, by and large, similar to that of adults. Conservative treatment is less effective for pediatric patients as compared with adults, even though it remains the first-line treatment for pediatric LDH. Chemonucleolysis can be attempted for certain patients after conservative treatment fails. Surgical treatment for pediatric LDH is associated with excellent short-term outcome regardless of which modality is chosen. Although the outcome begins to deteriorate in the mid-term follow-up, it remains good in the long run. Spinal fusion is not recommended for children and adolescents with only few exceptions. LDH does occur to children younger than 10 years and surgical treatment also provides successful solution.

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