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The Management of Symptomatic Lumbar Disc Herniation in Pregnancy: A Systematic Review

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Abstract

Study Design: Systematic review.

Objectives: Lumbar disc herniation (LDH) has been reported to affect 1 in 10 000 pregnant women. There is limited evidence available regarding the optimal management of LDH in pregnant patients. We aimed to review the current evidence for the management of symptomatic LDH in pregnancy through critical appraisal and analysis of the available literature.

Methods: Searches were conducted in Medline, Embase, PubMed, Science Direct, and The Cochrane Library from inception using predetermined search terms. All peer-reviewed studies of pregnant women with symptomatic LDH were included. The quality of eligible articles was assessed and extracted data and characteristics were pooled for analysis. References cited by studies were screened to identify other relevant publications.

Results: Thirty studies involving 52 patients were identified. Compared to surgically managed patients, conservatively managed patients had a higher full recovery rate (61.54% vs 56.41%) and reported a lower rate of persistent symptoms (30.77% vs 38.54%). Compared to patients who were treated surgically for cauda equina syndrome, patients treated surgically for sciatica had a higher full recovery rate (80.95% vs 27.78%) and reported a lower rate of persistent symptoms (14.29% vs 66.67%).

Conclusion: There is limited evidence to guide the management of pregnant patients with LDH. Despite a suggestion toward improved outcomes with conservative management, the presence of selection bias and the overall poor quality of current research precludes reliable conclusions from being drawn. Decision making for this patient group should be undertaken within a multidisciplinary setting.

Keywords
lumbar, disc, herniation, pregnancy

Introduction

Low back pain has been reported in up to 56% of pregnant women.[1] During pregnancy the increase in maternal abdominal girth leads to an anterior shift in the center of gravity.[2] To compensate for this there is an increase in lumbar lordosis and anterior tilt of the pelvis increasing the axial load through the spine.[3] Secretion of the polypeptide hormone relaxin rises during pregnancy, with concentrations peaking at the 12th week of gestation.[4] Relaxin is associated with remodeling of connective tissue, regulation of collagen, and softening of ligaments in the pelvis.[5] There may be analogous changes in the posterior

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longitudinal ligament, increasing the risk of intervertebral disc herniation.[5,6]

Lumbar disc herniation (LDH) is more prevalent in women of childbearing age although pregnancy is not considered an independent risk factor.[7] The prevalence of risk factors for LDH such as high body mass index and increased age are continuing to rise in the pregnant population, which some theorize may lead to a rise in the incidence of LDH.[8] LDH has been estimated to affect roughly 1 in 10 000 pregnant women, and less than 15% of women diagnosed with LDH suffer from severe neurological deficit or cauda equina syndrome (CES).[9,10]

It is recommended that pregnant women with LDH are treated conservatively unless nonsurgical management has failed or there are red flag symptoms.[11] Over 85% of pregnant patients with LDH report alleviation of symptoms within 6 weeks of conservative management.[10] Interventions for LDH in pregnancy must balance the risks and benefits of treatment for both the mother and fetus. It is imperative therefore that clinical decision making is undertaken by a multidisciplinary team (MDT) composed of obstetricians, neonatologists, surgeons and anesthetists.[12] If surgical management is indicated the effects of patient positioning, anesthesia, fetal heart rate monitoring, plans for urgent delivery, monitoring of maternal blood pressure, aspiration prophylaxis, and tocolysis for the prevention of preterm labor must be considered.

There is limited evidence available regarding the optimal management options for LDH in pregnancy. Most of the published literature consists of case reports, and there is currently no randomized controlled data available. While there are several narrative reviews available, there is no current systematic review for reference. The aim of this study was to systematically analyze and critically review the literature to determine the efficacy of different management strategies for pregnant patients with LDH.

Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed.[13] A literature search was carried out using 5 databases (Cochrane Library, PubMed, Medline, Embase, Science Direct) from inception. The search strategy (Appendix A, available in the online version of the article) used a combination of keywords and Medical Subject Headings (MeSH). The MeSH terms used in the search strategy were intervertebral disc displacement, disease management, pregnancy and lumbar vertebrae.

Inclusion and Exclusion Criteria

All studies that evaluated any intervention for treating symptomatic LDH during pregnancy were eligible for inclusion. Due to the limited clinical evidence available, case reports and case series were included. The methodology was adapted to follow the recommendations of the Cochrane Back Review Group.[14] In the studies selected, no restrictions were placed on the length of follow-up, publication date, or stage of pregnancy.

Study interventions were grouped into conservative and surgical management. Both epidural and general anesthetics were included as well as lateral and prone patient positioning during surgery.

Clinical and functional outcome measures were evaluated in studies where treatment was given during pregnancy and outcomes were reported at least once after treatment. Primary outcomes included the following:

- Pain intensity
- Neurological deficit including hypoesthesia, paraesthesia, and weakness
- Bowel or urinary symptoms
- Successful delivery of healthy infant

No secondary outcomes were analyzed.

Exclusion criteria were:

- Articles in languages other than English
- Participants whose onset of symptoms were while they were in labor
- Participants who had lumbar radiculopathy due to causes other than LDH
- Articles where the focus was on the prevention of LDH and not on treatment
- Articles where interventions were started prior to pregnancy but measured symptoms during pregnancy
- Meeting abstracts or conference proceedings

Identification of Studies

Studies identified by the search strategy were assessed for inclusion. Duplicates were removed and the remaining studies were screened using their titles. The remaining articles were reviewed and selected using their abstracts and removed if they did not fit the required eligibility criteria. Full texts were obtained of the residual articles. Further studies were found using the references of those established through the search strategy.

Quality Assessment

A quality assessment was carried out using the Joanna Briggs Institute Critical Appraisal Checklist for Case Reports (Appendix B, available in the online version of the article), which consists of 8 questions accounting for clear descriptions of the patient's demographics, history, presentation of clinical condition, the diagnostic tests used and their results, the intervention used, any adverse events, and the clinical outcome.

Data Extraction

A narrative synthesis of the findings from the included studies was conducted due to the heterogeneity of the studies and their

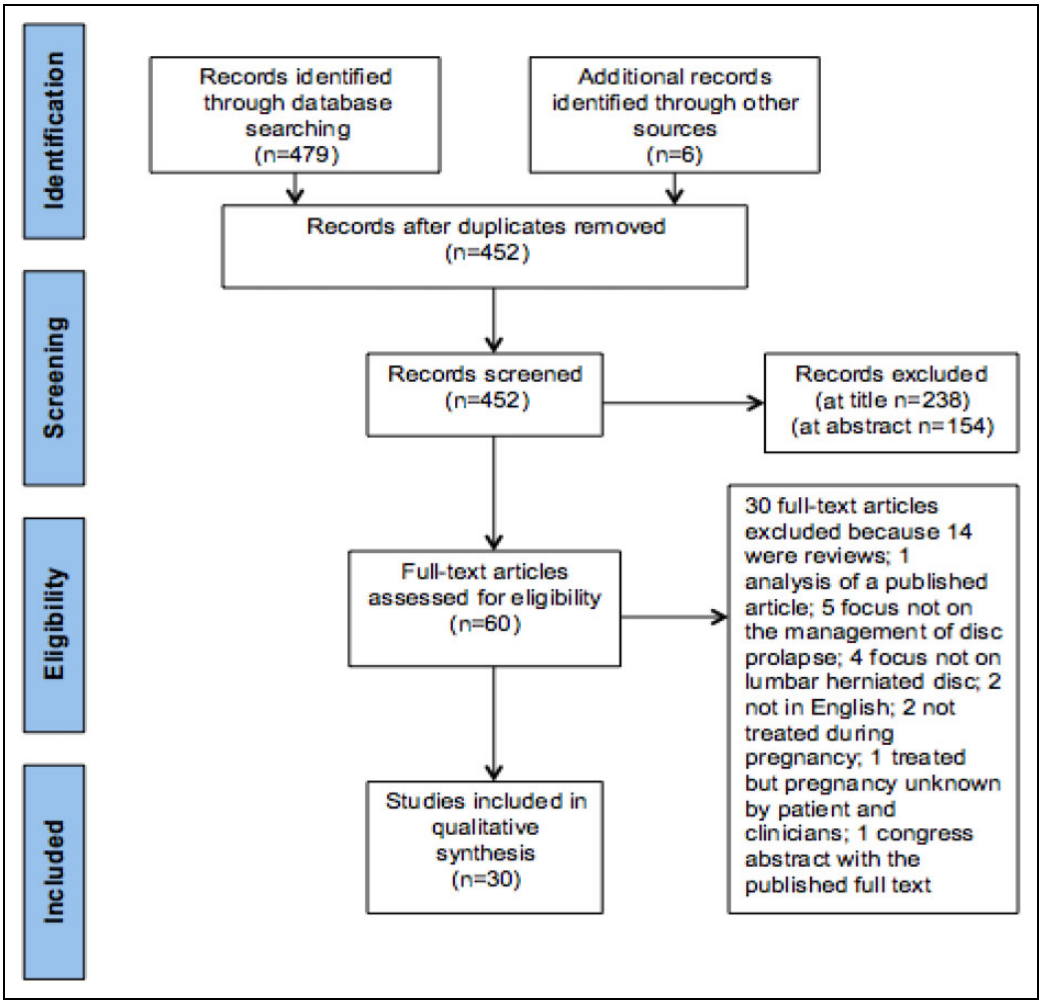

Figure 1. PRISMA flowchart illustrating the included and excluded studies.

results including differences in design, outcome, and measures of effect. Therefore, information was pooled into subgroups for analysis. Due to the heterogeneity of collated data and the limited information available, meta-analysis was not applicable.

Data Analysis

The results were analyzed narratively in subgroups comparing conservative and surgical managements through maternal outcomes, details of the birth, and time until follow-up. The surgical management subgroups were further divided into patients who were treated for sciatica and those who were treated for CES. Arithmetic means and percentages were calculated for comparison between the different interventions, the maternal outcomes, and the delivery. The demographics of the patients were also analyzed, evaluating how the patient's age and gestational age affected symptoms, diagnosis, and treatment.

Results

A systematic search of Medline, Embase, PubMed, Science Direct, and The Cochrane Library identified 479 articles. An additional 6 articles were found through the reference lists of these studies. Thirty-three duplicates were removed, leaving 452 articles to be screened. Of these, 238 records were excluded at the title stage and 154 at the abstract stage due to nonfulfilment of the inclusion criteria. The remaining 60 articles were screened using the full text, and a further 30 articles were excluded leaving 30 studies to be used in qualitative synthesis (Figure 1). Characteristics of the included studies can be found in Appendix C (available in the online version of the article).

Participant Demographics

From the 30 included studies, data was extracted from 52 pregnant women and used in this review. The age of the women in the included studies ranged from 24 to 41 years with a mean of 32.25 (SD = 3.45). For patients treated for symptoms of sciatica, the mean age was 31.60 years (SD = 2.95) with an age range of 24 to 38 years. Patients treated for symptoms of CES had a mean age of 33.4 years (SD = 3.98) and an age range of 26 to 41 years. The patient's gestational age ranged from 6 to 39 weeks with a mean of 24.40 weeks (SD = 8.91). For

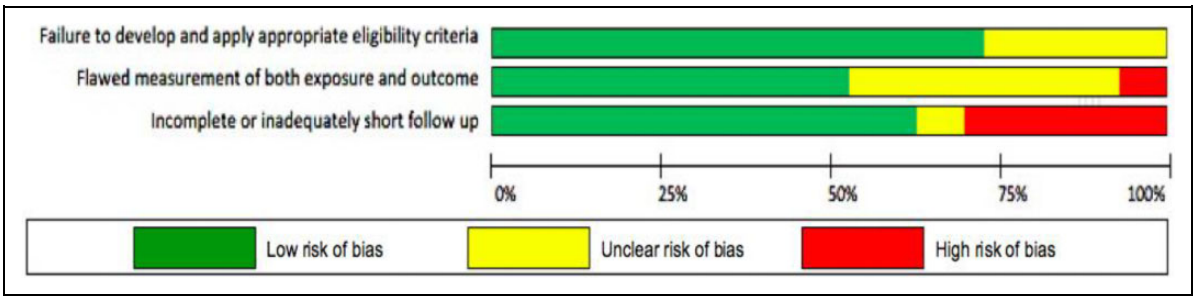

Figure 2. Summary of risk of bias.

patients treated for symptoms of sciatica, the mean gestational age was 23.90 weeks (SD = 8.70) with an age range of 6 to 38 weeks. Patients treated for symptoms of CES had a mean gestational age of 25.60 weeks (SD = 9.19) and a range of 9 to 39 weeks. A significant past medical history was reported in 9 women, including 6 patients with chronic LBP treated conservatively, 1 patient who was about to undergo lumbar disc excision before she found she was pregnant and the surgery was cancelled, 1 patient who had a history of laminectomy and pedicle screw fixation for an L3 burst fracture, and 1 patient who had a history of chronic lumbar back pain, sciatica, and degenerative disc disease. All of these patients had surgical management during their pregnancy due to worsening of their symptoms.

Interventions

Of the 52 women, 13 were treated conservatively and 39 treated surgically. Nine women underwent a discectomy in the left lateral position, 3 in the right lateral position, 19 in the prone position, and in 8 patients the position was not disclosed. Sixteen women received a general anesthetic, 4 women received regional (epidural or spinal) anesthesia, and the anesthetic management for 19 patients was undisclosed. Conservative treatment consisted of bed rest or immobilization, analgesia given orally, intramuscularly, or using an epidural, selective nerve root blocks, pelvic traction, thermotherapy, and transcutaneous neurostimulation.

Within the included studies it was reported that 29 patients had at least one follow-up after treatment and birth, ranging from 8 weeks to 40 months, with a mean time of 9.46 months (SD = 7.96).

The delivery of 10 patients was not reported but it was recorded that 16 patients had vaginal births, 24 had caesarean sections, 1 patient had a miscarriage at 11 weeks, and 1 patient had a therapeutic abortion at 16 weeks gestation due to inevitable radiation exposure during fusion surgery.

Bias

The included studies were all either case reports or case series, which limited their methodological quality and increased the risk of bias. A summary table assessing risk of bias and a risk of bias table for individual studies was constructed to depict the measurable influences (Figure 2 and Figure 3, respectively).

Measurement of Exposure and Outcome

There was sufficient information provided concerning the intervention used and the maternal and infant outcomes in 16/30 studies (53%). Twelve of 30 (40%) studies had some missing data, and 2/30 (7%) studies had insufficient data.

Follow-up

There was adequate follow-up (greater than 6 weeks) in 16/30 studies (53%), a follow-up of less than 6 weeks in 12/30 (40%), and no follow-up in 2/30 (7%) of studies.

Effects of Interventions

All reports used in this review included information on one or more patients experiencing symptoms from LDH, and a report on the management of these symptoms. Out of 30 studies and 52 patients, 6 studies (20%) reported 13 patients (25%) who were only treated conservatively, and 26 studies (80%) reported 39 patients (75%) who were treated surgically. For the patients who were treated surgically, 53.85% (n = 21) reported complete resolution of symptoms at follow-up and 38.46% (n = 15) of patients reported persistence of one or more symptoms. Complete resolution of symptoms was reported by 38.46% (n = 5) patients at follow-up who were treated conservatively, and 23.08% (n = 3) of patients reported persistence of one or more symptoms.

The studies were not amenable to meta-analysis primarily as they were of poor methodological quality and concerned small patient numbers, incomplete outcome data, and lack of randomization.

Conservative Management

For the 6 studies reporting the use of conservative management, Matsumoto et al was the only study that clearly outlined the patient's management program.[15] LaBan et al treated 5 patients with pelvic traction and thermotherapy, two of whom

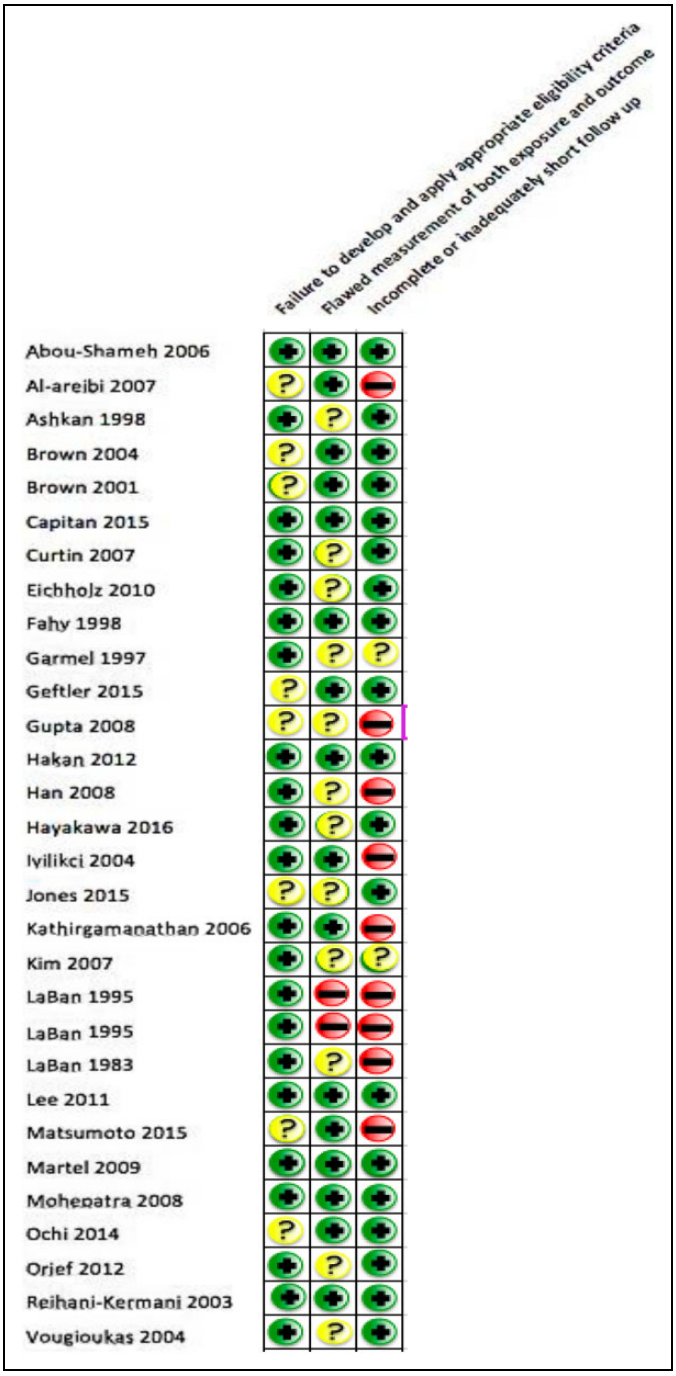

Figure 3. Risk of bias table for individual studies.

also received transcutaneous neurostimulation due to uncontrolled pain.[9] The outcomes of these patients are depicted in Figure 4. The outcome of the birth was not reported in 2 studies but 11 successful births took place with healthy infants. Follow-up was specifically reported in only 2 studies.[16,17]

Surgical Management

Surgical management was used in 90% (n = 27) of studies involving 45 patients. Data from 6 patients was not used in the evaluation of surgical management and prospective outcomes due to receiving surgical management 3 weeks postpartum (n = 5) and following miscarriage (n = 1). It was decided for 6 patients, with gestational age ranging from 32 to 39 weeks with a mean of 35.83 weeks (SD = 2.27), that caesarean sections should be carried out immediately before surgery to manage the LDH. The exact indications for surgery differed between studies. The majority of patients underwent surgery due to symptoms consistent with CES or progressive motor deficit. A small number of patients underwent surgery for intractable radicular pain resistant to conservative measures. The positioning of patients, use of anesthetic, and type of surgery are illustrated in Table 1.

Patient outcomes are shown in Figure 5. These outcomes have been broken down further into patients reporting symptoms of CES and those with symptoms of sciatica for direct comparison (Figure 6). Twenty-one patients were surgically treated for symptoms of sciatica, and 18 patients were surgically treated for symptoms of CES. Of the patients treated for sciatica, 80.95% (n = 17) had full resolution of symptoms, 9.52% (n = 2) had hypoesthesia, 4.76% (n = 1) had weakness, 4.76% (n = 1) had foot drop, and symptoms were not reported in 4.76% (n = 1). Of the patients treated for CES, 27.78% (n = 5) had full resolution of their symptoms, 22.22% (n = 4) had persistent bladder and bowel symptoms, 50.00% (n = 9) had hypoesthesia, 11.11% (n = 2) had weakness, 5.56% (n = 1) had paraesthesia, 5.56% (n = 1) had foot drop, and symptoms were not reported in 5.56% (n = 1).

The outcome of the birth was not reported in 20.51% (n = 8) patients, but 74.36% (n = 29) successful births took place with healthy infants and mothers. One patient miscarried at 11 weeks and continued to have surgical treatment thereafter, while another patient had a therapeutic abortion at 16 weeks gestation due to inevitable radiation exposure during fusion surgery. Follow-up ranged from 6 weeks to 48 months with a mean of 11 months (SD = 10.73) but was not reported for 8 patients.

Discussion

The demographics, management, and outcomes of 30 case reports or case series involving 52 patients were collated and compared through systematic review.

Patients treated conservatively had a higher rate of full resolution of symptoms than surgically treated patients (61.54% compared to 56.41%), and a lower rate of prolonged symptoms postmanagement (30.77% compared to 38.54%). For patients who were treated surgically for symptoms of sciatica, a higher full recovery rate was found compared to patients who were treated surgically for CES (80.95% compared to 27.78%) and a lower rate of persistent symptoms were reported (14.29% compared to 66.67%). This could be due to sciatica having a better prognosis for permanent neurological sequelae than CES with or without treatment, and that all CES patients are surgically managed. Patients who receive surgical treatment are more likely to have more severe symptoms than those treated conservatively

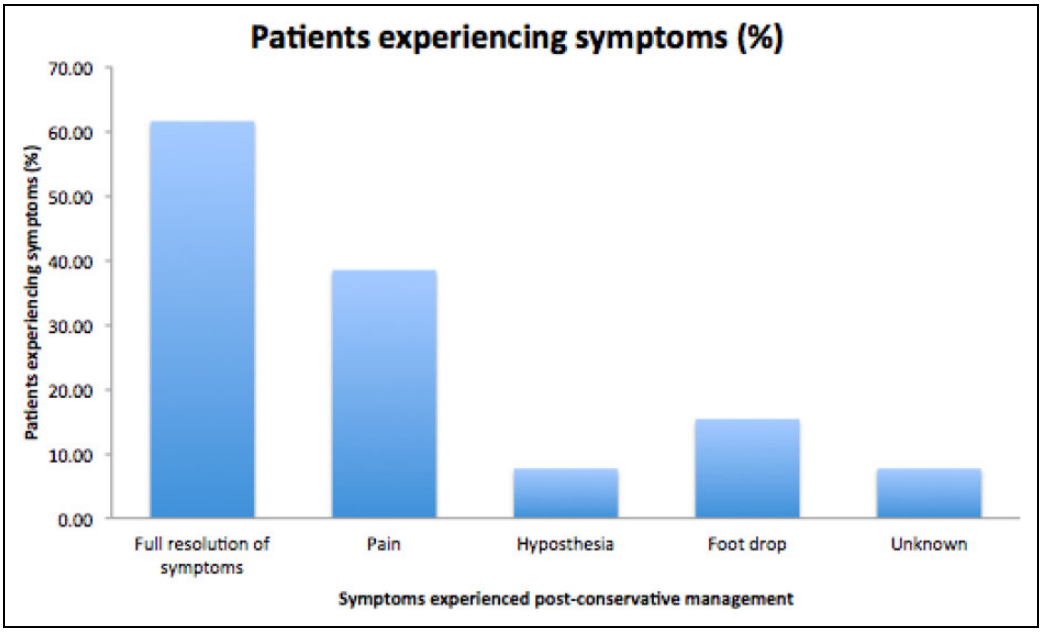

Figure 4. Symptoms reported by patients during follow-up, post-conservative treatment.

prior to treatment. This selection bias forms a considerable confounding factor, and we cannot confidently conclude that conservative management is superior to surgical intervention.

Patients treated conservatively reported a 100% successful birth rate with a healthy mother and infant compared with 93.55% of patients treated surgically.

A systematic review by Di Martino et al concluded that with improving multidisciplinary management, surgical management of LDH in pregnancy is safe.[18] However, they were unable to conclude whether surgical or conservative management produces superior outcomes. Ardaillon et al recently published a narrative review that discussed how the optimal surgical approach depends on the stage of pregnancy but they did not consider conservative management.[12]

Implications for Practice

The management of patients with LDH should be planned by an MDT. Over 85% of patients will have improved symptoms within 6 weeks of commencing conservative methods of treatment.[19] Surgery may be required in patients with severe intractable back and leg pain that is unresponsive to conservative treatment, progressive neurological deficits, or CES.[20-25] Beyond 24 weeks of gestation, neonatal survival rates are greater than 80%.[26,27] It is therefore recommended surgical treatment should be delayed beyond 24 weeks gestation unless patients present with severe and or progressive neurological deficits.[28] Surgical intervention of LDH is not contraindicated in pregnancy according to some authors,[20,21,29] although Matsumoto et al disagree with this notion and advocate a more conservative approach.[15]

However, in the presence of progressive neurological deficits and intractable pain where maternal stress can increase the risk of abortion or preterm birth, it is reasonable to consider surgery as an option.[11,30]

The ACOG (American College of Obstetricians and Gynecologists) recommends postponing procedures until after delivery or at least until the second trimester when the risk of spontaneous abortion is lower,[31] although it is recognized that surgery cannot always be delayed and is still indicated regardless of the trimester. Maternal safety is a priority in management of patients; maternal hypoxia, hypocarbia, and hypotension should be avoided and preterm labor prevented.[31,32] Magnetic resonance imaging is not contraindicated in pregnancy and can be safely used to investigate for LDH.[20,21,33,34]

Conservative management primarily consists of bed rest and oral analgesia. Pain should be managed according to the World Health Organization analgesic ladder while nonsteroidal anti-inflammatory drugs should be avoided. If symptoms persist beyond 3 to 4 weeks of bed rest, oral analgesia, epidural or transforaminal steroid injections can be considered.

Optimal intraoperative patient positioning depends on the gestational age.[22,28] The prone position is not recommended beyond 12 weeks of gestation[22,35] without the use of a Relton-Hall laminectomy frame as it can cause abdominal compression, inciting preterm labour.[21,36-38] A left lateral position is preferable for patients in later stages of the second trimester and the third,[28] providing superior surgical exposure while avoiding aortocaval compression.[17,22,29,33,39]

Pregnancy is not a contraindication for general or regional anaesthesia.[20,21,33,40] Regional anesthesia is recommended for use in shorter operations.[41] General anesthesia should be used

Table 1. Details of Surgery Carried Out for 39 Patients Including Positioning and Anesthetic.

Positioning	Surgery	Anesthetic
Left lateral	Interlaminar	GA
Prone	Microdiscectomy	GA
Prone	Hemilaminectomy, medial facetectomy, microdiscectomy, and foraminotomy	GA
Prone	Laminoforaminotomy and discectomy	GA
Prone	Hemilaminectomy and microdiscectomy	GA
Prone	Hemilaminectomy and microdiscectomy	GA
Left lateral	Information not given	GA
Left lateral	Discectomy	Information not given
Prone	Discectomy	GA
Left lateral	Discectomy and nerve root decompression	GA
Prone	Discectomy	GA
Prone	Laminectomy and discectomy	GA
Left lateral	Nucleotomy	Information not given
Left lateral	Nucleotomy	Information not given
Left lateral	Discectomy	GA
Prone	Laminectomy	Epidural
Prone	Laminectomy	Epidural
Prone	Laminectomy and partial facetectomy	Epidural
Information not given	Information not given	Information not given
Information not given	Information not given	Information not given
Information not given	Information not given	Information not given
Information not given	Laminectomy and discectomy	Information not given
Prone	Discectomy	Information not given
Right lateral	Discectomy	Information not given
Right lateral	Discectomy	Information not given
Prone	Laminectomy and discectomy	GA
Information not given	Laminectomy	Information not given
Prone	Discectomy	Epidural
Information not given	Discectomy	Information not given
Information not given	Discectomy and decompression	Information not given
Prone	Laminectomy and discectomy	GA
Prone	Partial hemilaminectomy and discectomy	Information not given
Prone	Posterior lumbar interbody fusion	Information not given
Right lateral	Hemilaminectomy and discectomy	Information not given
Left lateral	Hemilaminectomy and discectomy	Information not given
Left lateral	Hemilaminectomy and discectomy	Information not given
Right lateral	Hemilaminectomy and discectomy	Information not given
Prone	Information not given	GA
Prone	Information not given	GA

Abbreviation: GA, general anesthesia.

with caution in the first trimester due to an increased risk of spontaneous abortion.[42] The ACOG recommends that regional anesthesia is preferred as it reduced fetal drug exposure.[31] However, regional anesthesia is not without risks and can cause sudden hypotension, potentially resulting in fetal distress and preterm labour.[28,43]

Fetal Heart Monitoring

The ACOG states that the use of intraoperative fetal heart monitoring should be determined by an MDT based on each patient and the surgery to be performed; however, it is recommended all viable fetuses are monitored wherever possible.[31]

Delivery

There is controversy regarding the optimal route of delivery for patients who do not undergo a caesarean section at the time of surgery for the LDH. Some physicians recommend women undergo a caesarean section to prevent further deterioration of lumbar spine symptoms,[8,44,45] although women with vaginal delivery do not report an elevated rate of persistent neurological symptoms.[44] Brown et al stated that inducing labor before treatment for LDH can cause increased neurological injury due to the rise of epidural venous pressure that occurs during labour.[35] Pending higher quality evidence, the route of delivery should be considered by an MDT composed of obstetricians, neonatologists, surgeons, and anesthetists. Figure 7 illustrates an algorithm for the management of pregnant patients with symptomatic LDH.

Implications for Research

The limited quality of the evidence available highlights an important gap in the literature. However, there are considerable ethical difficulties in recruiting pregnant women to randomized studies. The National Commission and Federal Regulations permit pregnant women to participate in clinical research if the purpose of the activity is to meet the health needs of the mother regardless of the degree of risk to the fetus. However, the ethics underpinning treatment during pregnancy depends not only on how an intervention affects the mother's health but also on its risk to the fetus. A risk analysis is therefore mandatory.[29]

The studies included in this review lacked quantitative patient-reported outcome measures. Such measures must be

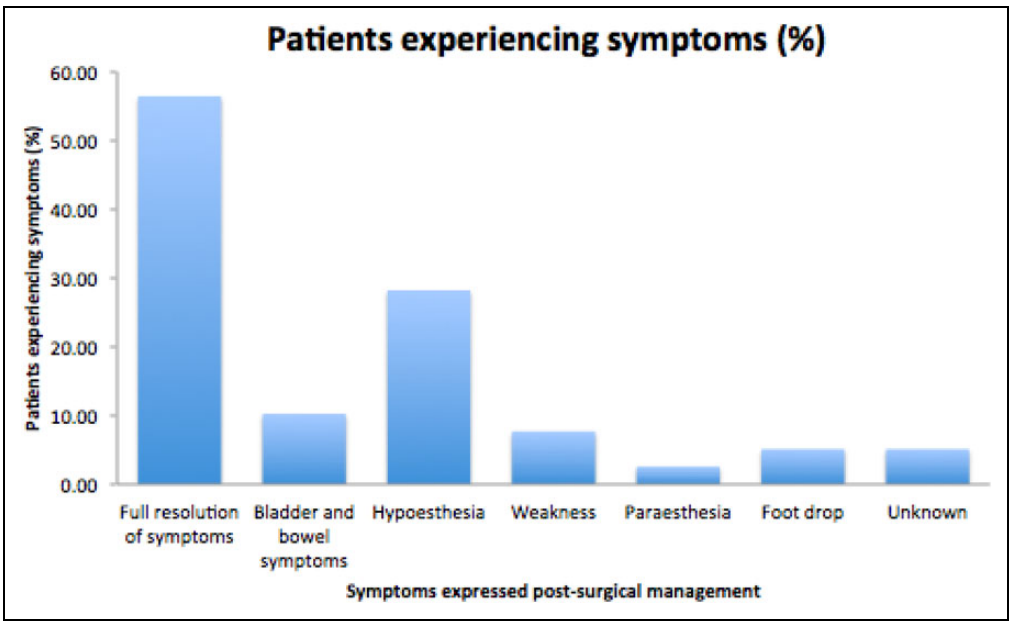

Figure 5. Symptoms reported by patients during follow-up, post-surgical treatment.

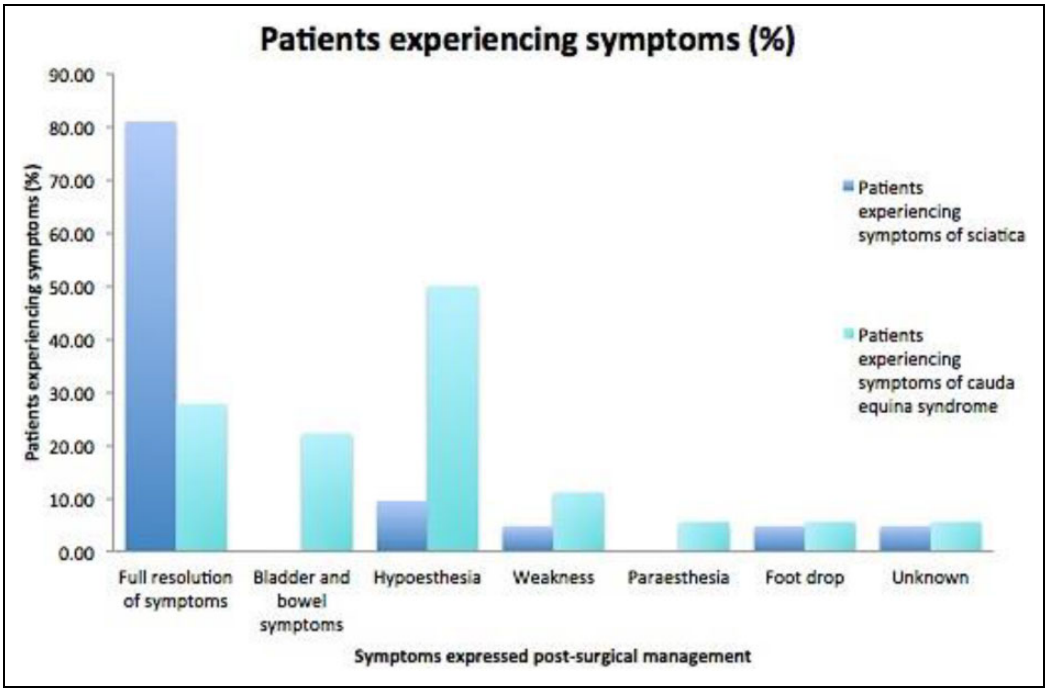

Figure 6. Symptoms reported by patients during follow-up, post-surgical treatment, divided into cauda equina syndrome and sciatica.

used in the reporting of patient symptoms to enable reliable comparison of treatment effect.

Limitations

This systematic review was limited by the small number of studies and patient numbers (30 studies, 52 patients) available in the published literature. Studies had poor methodological quality with a high risk of bias, lack of randomization, and incomplete outcome data. Selection bias in these studies was a significant confounder, preventing reliable conclusions from being drawn about conservative versus surgical management.

The reports included women at various times in their pregnancies, with varying symptoms and interventions using a variety of quantitative and qualitative data to measure effect of

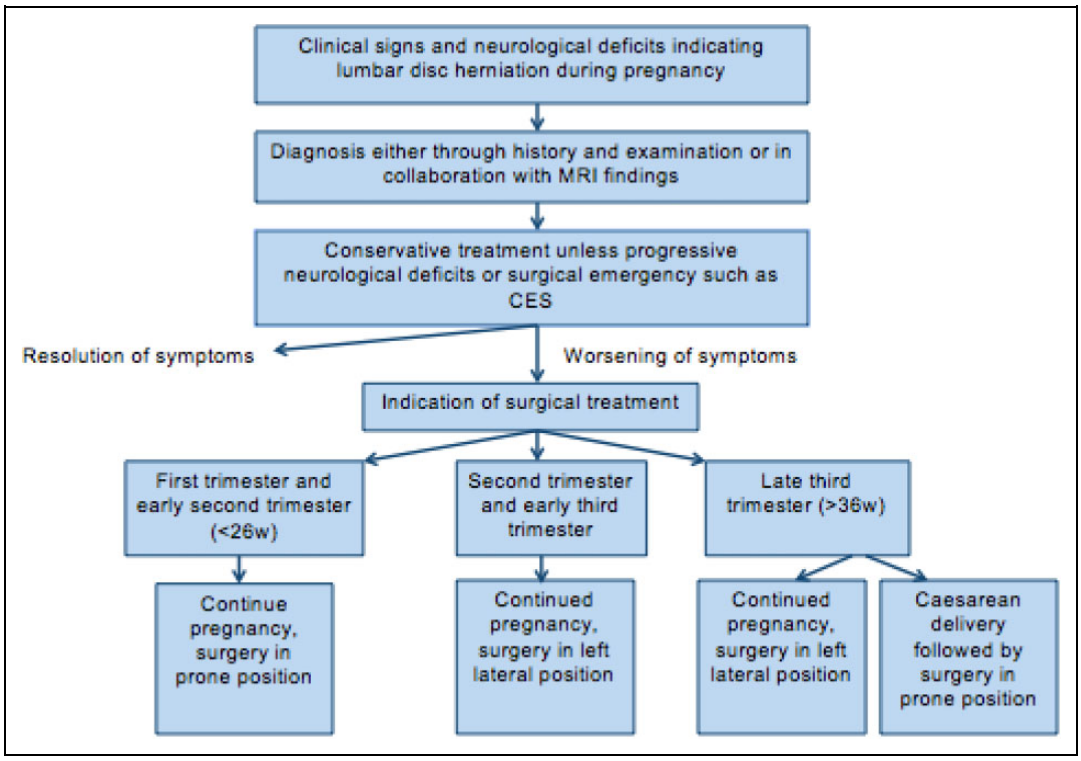

Figure 7. An algorithm for the management of pregnant patients with symptomatic LDH. Adapted from Ardaillon et al.[12]

interventions making data not directly comparable. Follow-up was not reported in 9 studies[9,15,22,29,33,41,45-47] and was carried out less than 6 weeks postmanagement in 2 studies,[11,21] therefore causing a high risk of attrition bias and failure to address the maternal and infant outcomes over a longer time. Matsumoto et al concluded that the patient's symptoms were relieved postpartum due to a return of normal spinal posture and the reduction of intraabdominal pressure, not as a result of the treatment given.[15]

Finally, there was limited representation of patients' baseline function, preventing comparisons to be made pre- and posttreatment.

Conclusion

All pregnant patients with intractable symptoms or progressive neurology as a result of LDH should have their management discussed within an MDT. There are currently no guidelines to inform the management of these patients, leading to delayed diagnosis and treatment with a greater risk of chronic neurological sequelae. The current literature is not of sufficient quality to allow reliable conclusions to be drawn about the management of LDH within the pregnant population.

Declaration of Conflicting Interests

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Supplemental Material

The supplemental material is available in the online version of the article.

References

1. Fast A, Shapiro D, Ducommun EJ, Friedmann LW, Bouklas T, Floman Y. Low-back pain in pregnancy. *Spine (Phila Pa 1976)*. 1987;12:368-371.
2. Walde J. Obstetrical and gynecological back and pelvic pains, especially those contracted during pregnancy. *Acta Obstet Gynecol Scand Suppl*. 1962;41(suppl 2):11-53.
3. Ritchie JR. Orthopedic considerations during pregnancy. *Clin Obstet Gynecol*. 2003;46:456-466.
4. Kristiansson P, Svärdsudd K, von Schoultz B. Serum relaxin, symphyseal pain, and back pain during pregnancy. *Am J Obstet Gynecol*. 1996;175:1342-1347.
5. Katonis P, Kampouroglou A, Aggelopoulos A, et al. Pregnancy-related low back pain. *Hippokratia*. 2011;15:205-210.
6. O'Connell JE. Lumbar disc protrusions in pregnancy. *J Neurol Neurosurg Psychiatry*. 1960;23:138-141.

7. Weinreb JC, Wolbarsht LB, Cohen JM, Brown CE, Maravilla KR. Prevalence of lumbosacral intervertebral disk abnormalities on MR images in pregnant and asymptomatic nonpregnant women. *Radiology*. 1989;170(1 pt 1):125-128.
8. Curtin P, Rice J. Cauda equina syndrome in early pregnancy: a case report. *Acta Obstet Gynecol Scand*. 2007;86:758-759.
9. LaBan MM, Perrin JC, Latimer FR. Pregnancy and the herniated lumbar disc. *Arch Phys Med Rehabil*. 1983;64:319-321.
10. Fager CA. Observations on spontaneous recovery from intervertebral disc herniation. *Surg Neurol*. 1994;42:282-286.
11. Hakan T. Lumbar disk herniation presented with cauda equina syndrome in a pregnant woman. *J Neurosci Rural Pract*. 2012; 3:197-199.
12. Ardaillon H, Laviv Y, Arle JE, Kasper EM. Lumbar disk herniation during pregnancy: a review on general management and timing of surgery. *Acta Neurochir (Wien)*. 2018;160: 1361-1370.
13. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6: e1000097.
14. Furlan AD, Malmivaara A, Chou R, et al; Editorial Board of the Cochrane Back, Neck Group. 2015 Updated method guideline for systematic reviews in the Cochrane Back and Neck Group. *Spine (Phila Pa 1976)*. 2015;40:1660-1673.
15. Matsumoto E, Yoshimura K, Nakamura E, Hachisuga T, Kashimura M. The use of opioids in a pregnant woman with lumbar disc herniation: a case report. *J Opioid Manag*. 2009;5:379-382.
16. Orief T, Orz Y, Attia W, Almusrea K. Spontaneous resorption of sequestrated intervertebral disc herniation. *World Neurosurg*. 2012;77:146-152.
17. Vougioukas VI, Kyroussis G, Gläsker S, Tatagiba M, Scheufler KM. Neurosurgical interventions during pregnancy and the puerperium: clinical considerations and management. *Acta Neurochir (Wien)*. 2004;146:1287-1292.
18. Di Martino A, Russo F, Denaro L, Denaro V. How to treat lumbar disc herniation in pregnancy? A systematic review on current standards. *Eur Spine J*. 2017;26(suppl 4):496-504.
19. Dupont J, Pierre A, Froment P, Moreau C. The insulin-like growth factor axis in cell cycle progression. *Horm Metab Res*. 2003;35: 740-750.
20. Brown MD, Levi AD. Surgery for lumbar disc herniation during pregnancy. *Spine (Phila Pa 1976)*. 2001;26:440-443.
21. Kim HS, Kim SW, Lee SM, Shin H. Endoscopic discectomy for the cauda equina syndrome during third trimester of pregnancy. *J Korean Neurosurg Soc*. 2007;42:419-420.
22. Han IH, Kuh SU, Kim JH, et al. Clinical approach and surgical strategy for spinal diseases in pregnant women: a report of ten cases. *Spine (Phila Pa 1976)*. 2008;33:E614-E619.
23. Ng J, Kitchen N. Neurosurgery and pregnancy. *J Neurol Neurosurg Psychiatry*. 2008;79:745-752.
24. Han IH. Pregnancy and spinal problems. *Curr Opin Obstet Gynecol*. 2010;22:477-481.
25. Smith MW, Marcus PS, Wurtz LD. Orthopedic issues in pregnancy. *Obstet Gynecol Surv*. 2008;63:103-111.
26. Ogawa M, Matsuda Y, Kanda E, et al. Survival rate of extremely low birth weight infants and its risk factors: case-control study in Japan. *ISRN Obstet Gynecol*. 2013;2013: 873563.
27. Su BH, Hsieh WS, Hsu CH, et al. Neonatal outcomes of extremely preterm infants from Taiwan: comparison with Canada, Japan, and the USA. *Pediatr Neonatol*. 2015;56:46-52.
28. Hayakawa K, Mizutani J, Suzuki N, et al. Surgical management of the pregnant patient with lumbar disc herniation in the latter stage of the second trimester. *Spine (Phila Pa 1976)*. 2017;42: E186-E189.
29. Kathirgamanathan A, Jardine AD, Levy DM, Grevitt MP. Lumbar disc surgery in the third trimester—with the fetus in utero. *Int J Obstet Anesth*. 2006;15:181-182.
30. Abou-Shameh MA, Dosani D, Gopal S, McLaren AG. Lumbar discectomy in pregnancy. *Int J Gynaecol Obstet*. 2006;92: 167-169.
31. ACOG Committee on Obstetric Practice. ACOG Committee Opinion No. 474: nonobstetric surgery during pregnancy. *Obstet Gynecol*. 2011;117(2 pt 1):420-421.
32. Gupta A, Verma A, Sood R. Postoperative monitoring in pregnant patients undergoing surgery for advanced malignancy in last trimester: how long is enough? *J Anaesthesiol Clin Pharmacol*. 2014;30:284-286.
33. Iyilikçi L, Erbayraktar S, Tural AN, Celik M, Sannav S. Anesthetic management of lumbar discectomy in a pregnant patient. *J Anesth*. 2004;18:45-47.
34. Reihani-Kermani H. Cauda equina syndrome in pregnancy. *Arch Iranian Med*. 2003;5:146-148.
35. Brown MD, Brookfield KF. Lumbar disc excision and cesarean delivery during the same anesthesia. A case report. *J Bone Joint Surg Am*. 2004;86-A:2030-2032.
36. Ochi H, Ohno R, Kubota M, et al. Case report: the operation for the lumbar disk herniation just after cesarean delivery in the third trimester of pregnancy. *Int J Surg Case Rep*. 2014;5: 1178-1182.
37. Jones CS, Patel S, Griffiths-Jones W, Stokes OM. Presentation of cauda equina syndrome during labour. *BMJ Case Rep*. 2015; 2015:bcr2015212119.
38. Capitán BA, Torán MM. The cauda equina syndrome in pregnant woman with a massive disc herniation [in Spanish]. *Rev Esp Cir Ortop Traumatol*. 2017;61:63-65.
39. Lee JM, Han IH, Moon SH, Choi BK. Surgery for recurrent lumbar disc herniation during pregnancy: a case report. *Korean J Spine*. 2011;8:304-306.
40. Geftler A, Sasson A, Shelef I, Perry ZH, Atar D. Cauda equina syndrome in a 36 week gravida patient. *Isr Med Assoc J*. 2015;17: 522-523.
41. Al-Areibi A, Coveney L, Singh S, Katsiris S. Case report: anesthetic management for sequential Cesarean delivery and laminectomy. *Can J Anaesth*. 2007;54:471-474.
42. Borg-Stein J, Dugan SA, Gruber J. Musculoskeletal aspects of pregnancy. *Am J Phys Med Rehabil*. 2005;84:180-192.
43. Douglas J, Choi D. Spinal anesthesia for obstetrics: discovery, rediscovery. *Can J Anaesth*. 2000;47:833-836.

44. Berkmann S, Fandino J. Pregnancy and childbirth after microsurgery for lumbar disc herniation. *Acta Neurochir (Wien)*. 2012; 154:329-334.
45. LaBan MM, Rapp NS, von Oeyen P, Meerschaert JR. The lumbar herniated disk of pregnancy: a report of six cases identified by magnetic resonance imaging. *Arch Phys Med Rehabil*. 1995;76:476-479.
46. Gupta P, Gurumurthy M, Gangineni K, Anarabasu A, Keay SD. Acute presentation of cauda equina syndrome in the third trimester of pregnancy. *Eur J Obstet Gynecol Reprod Biol*. 2008;140:279-281.
47. LaBan MM, Viola S, Williams DA, Wang AM. Magnetic resonance imaging of the lumbar herniated disc in pregnancy. *Am J Phys Med Rehabil*. 1995;74:59-61.