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REVIEW

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Gas accumulation in the spinal canal: a systematic review and a novel CT-based classification

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Abstract

Objectives This systematic review aims to further explore the relationship between image and clinical features of spinal gas accumulation, propose a novel clinical classification based on CT images and clinical outcomes of surgical treatment and provide insights for new therapeutic strategies.

Materials and methods Studies with data on gas accumulation in the spinal were retrieved by searching PubMed, Embase, and Web of Science from inception to August 20, 2023, and screened following the PRISMA guidelines. Characteristic information, CT and MRI morphologic features, and surgical results of patients with gas accumulation in the spinal were reviewed, and patients were categorized according to preoperative CT findings.

Results A total of 41 articles were retrieved from the works of literature, including 53 patients with complete data. Among them, there were 29 males (59.70%) and 24 females (40.30%), with an average age of 65.8 years. We identified four types of gas accumulation in the spinal: Pseudocyst as pure gas (TypeI) with 34 cases (64.1%), Air cyst as epidural gas with a thin wall (TypeII) with 7 cases (13.2%), Air-contained disc herniation as epidural gas with disc herniation (Type III) with 3 cases (5.7%), intradural type (Type IV) with 9 cases(17.0%). 25 patients with Type I underwent non-conservative treatment and mild adhesions were observed in three patients. Adhesions were observed in 5 of the 6 Type II patients treated operatively. No adhesion was observed in three Type III patients. Adhesion was observed in 4 of 9 Type IV patients.

Conclusion Gas accumulation in the spinal canal is a common clinical disease, which can be identified by CT and MRI. The classification based on CT scans helps guide clinical treatment.

Keywords Gas, Cyst, Pseudocyst, CT, Classification, Spine

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Introduction

The abnormal accumulation of gas within the spinal canal is known as intraspinal gas accumulation, which can accumulate within the intradural, extradural, lateral recess, or extreme lateral space. Typically, it only manifests as abnormal imaging findings, without obvious symptoms [1], when the gas volume increases to a certain extent, there may be different clinical manifestations [2, 3]. Over the past two decades, with the aging of the population and the advancement of imaging techniques, the detection of intraspinal gas accumulation has gradually increased [2, 4–8]. As one of the differential diagnoses of radiculopathy, its low incidence may lead to a missed diagnosis or misdiagnosis.

There are few reports on gas accumulation in the spinal canal, most of them were case reports and case series [3, 6, 8–13]. Murat systematically reviewed previous case reports and summarized the common clinical features of intraspinal gas accumulation: it was commonly diagnosed at the lower lumbar spine (L4-L5, 45.3%; L5-S1, 37.7%), and it frequently occurred in older ages patients, especially in patients > 60 years old. However, radiological images were neglected in this study [14]. Liu reviewed imaging data from 110 patients with extradural gas accumulation and proposed common classifications of CT (pseudocyst as pure gas, air cyst as epidural gas with a thin wall, air-contained disc herniation as epidural gas with disc herniation, and honeycomb-like air cyst as disc herniation within multiple gas bubbles) and explored the relationship between classification and nerve root lesions. However, this classification was not consistent with clinical symptoms [1]. To further explore the relationship between imaging and clinical characteristics, as well as surgical treatment, we reviewed previously reported cases and attempted to classify spinal gas accumulation based on CT scans, providing insights for new treatment strategies.

Materials and methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [15] and JBI Critical Appraisal Checklist for case reports (JBI) [16].

Inclusion and exclusion criteria

Inclusion criteria are as follows: (1) Case reports with complete data; (2) CT imaging data available; (3) The JBI quality level was high quality.

Exclusion criteria are as follows: (1) Articles not written in English; (2) Cysts without containing gas; (3) Letters, conferences and reviews.

A systematic review of the literature

The articles were searched online in three different literature databases (PubMed, Embase and Web of Science) on August 20rd, 2023. The search terms were ((epidural) OR (intraspinal) OR (intradural) OR (disc herniation)) AND (gas) AND ((cyst) OR (pseudocyst)). Only relevant articles and their references were included in the current study. The flow chart detailed our search process (Fig. 1).

Data extraction

Two independent reviewers extracted relevant information from each selected study. The data contained: the first author`s name, year of publication, patients` age, gender, symptoms, presence of a vacuum phenomenon, lesion location, surgical approach, intraoperative adhesions, postoperative pathology, and postoperative outcomes.

Quality assessment

The JBI Checklist is utilized to assess the quality of individual case reports. The JBI checklist consists of eight questions, with answer options of "yes", "no", "unclear", or "not applicable". Consequently, when the answer is "yes," it is scored as one point, resulting in a total score of eight. The JBI score is then categorized as poor quality, moderate quality, or high quality, with scores ranging from 0 to 3, 4–5, and 6–8, respectively.

Statistical analysis

The data was analyzed using the SPSS 20.0 version (IBM, Ammonk, New York, USA). Categorical variables were presented as absolute numbers and percentages.

Results

A systematic review of the literature

A total of 40 articles were retrieved from the literature [2–6, 8, 9, 11, 17–29], including 53 patients with complete data. Among them, there were 29 males (54.7%) and 24 females (45.3%), with an average age of 65.8 years. The information included in the case is shown in Table 1.

Types of gas accumulation in the spinal canal

We have determined four main types of gas accumulation in the spinal on CT: pseudocyst as pure gas (TypeI), air cyst as epidural gas with a thin wall (TypeII), air-contained disc herniation as epidural gas with disc herniation (Type III), intradural type (Fig. 2). Type I was found in 34 cases (Fig. 2a), due to the absence or only a small amount of high-density area (Orange) of gas (Blue) at the axial CT and the soft tissue boundary (White), it presents as a simple pure gas. Air cyst as epidural gas with a thin wall (TypeII) was found in 7 cases (Fig. 2b), on axial CT, the gas (Blue) exhibited a distinct annular high-density area (Orange) in relation to the surrounding soft tissue

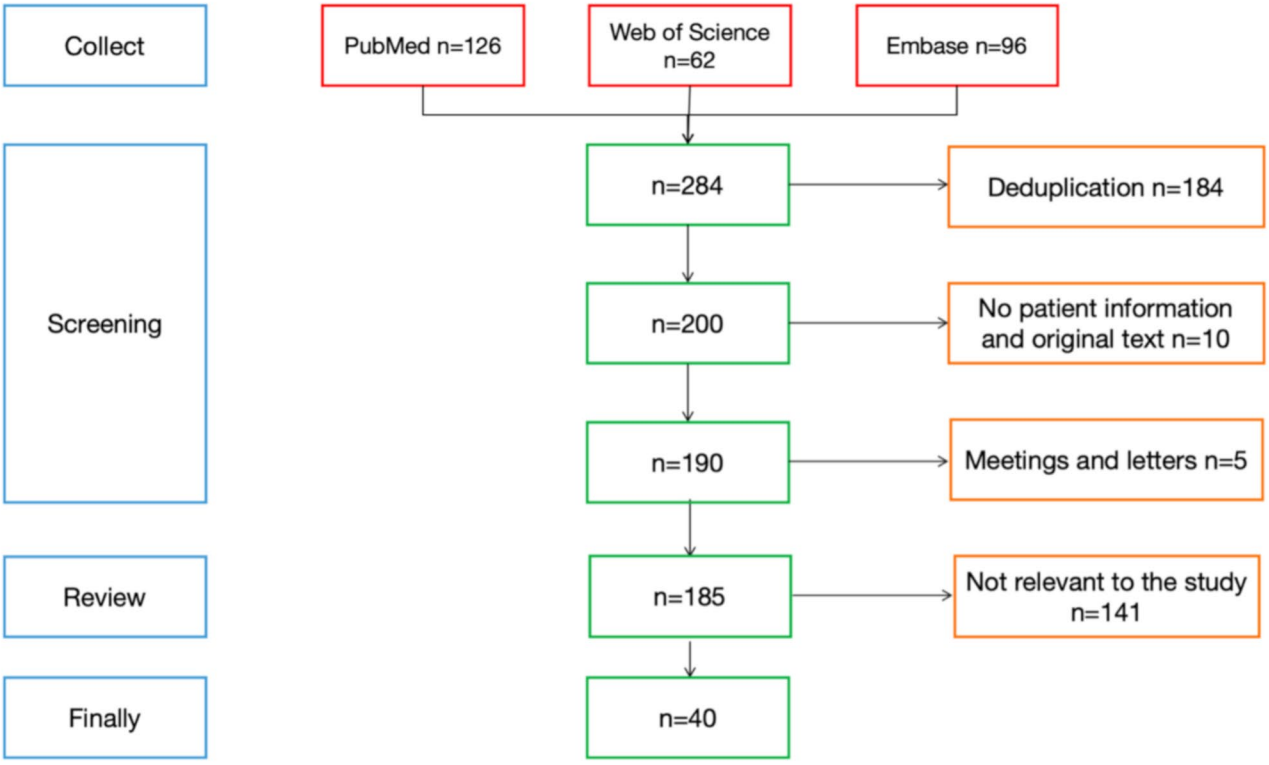

Fig. 1 PRISMA flowchart of systematic literature review for gas accumulation in the spinal canal cases

(White), making it easy to differentiate the high-density area from the surrounding soft tissue and gas. Air-contained disc herniation as epidural gas with disc herniation (Type III) was found in 3 cases (Fig. 2c), which can be seen on the axial CT with protruding intervertebral disc containing gas, the gas could be single or multiples. The intradural type (Type IV) was found in 9 cases (Fig. 2d), which can be seen in the middle of the spinal canal on the axial CT, and in some cases, a circular high-signal area surrounding the low signal can be observed on enhanced MRI.

Clinical characteristics of 4 types of spinal gas accumulation

A total of 34 patients were found to be the TypeI(Table 2). Type Iprevalently occurred in the elderly (>60 years: 73.5%), the lesion site was common in the lower lumbar spine (L4-L5,40.0%; L5-S1,34.3%), and vacuum sign was common (64.7%). 55.9% patients suffered from sciatica and 52.9% patients received surgery as the first choice. In the entire cohort, 82.4% of patients had a full recovery. There were 7 patients with TypeII(Table 3), predilection in the elderly (>60 years 85.7%), the most common symptom was lower radiating pain (57.1%), common in the lower lumbar spine (L4-L5, 43.9%; L5-S1, 28.6%), and all had a vacuum phenomenon (100%). Except for 1 patient with no reported treatment, four patients opted for surgery, two patients opted for interventional therapy, and one of the patients relapsed and underwent interventional therapy again. All patients recovered completely. There were 3 patients with Type III (Table 2), Type III prevalently occurred in the elderly (>60 years: 66.7%), the lesion site was in the lower lumbar spine only 50%, and vacuum sign was common (66.7%). 2 patients selected for operation recovered completely, 1 patient selected for conservative treatment only partially recovered. There were 9 patients with Type IV (Table 4), which also occurred in the elderly (>60 years; 88.9%). The most common symptom was lower radiating pain (44.4%), the common lesion site was in L2-L3(33.3%) and L3-L4(44.4%). And vacuum is common (55.6%), enhanced magnetic resonance imaging indicated high signal around the gas-containing cysts in five patients. Surgery was the first choice for most patients (88.9%). All patients had a full recovery.

Intraoperative adhesion

As adhesion was not defined in previous studies, it was defined as intraoperative adhesion in our study. 25 patients with Type I underwent surgical treatment, adhesion was observed in 3 patients. Adhesion was observed in 5 of the 6 Type II patients treated operatively. No adhesion was observed in 3 Type III patients. Adhesion was observed in 4 of 9 Type IV patients (Table 5).

Table 1 Patients treated for intradural gas accumulation reported in the literature

Authors/year	Patients	Age/gender	Presentation	Vacuum sign	Level	Treatment	Outcome
Z. Wei/2023	1	52/F	LLRP	YES	L4-L5	Surgery	Relief
Yamada/2022	2	70/F	RHRP	NO	C4-C5	Surgery	Relief
Prasad Krishnan/2022	3	50/M	LBP + RHRP	YES	L5-S1	Conservative	Partial Relief
Dong Hu/2022	4	59/M	RLRP	YES	L5-S1	Surgery	Relief
H.L. Ferjani/2021	5	78/M	LBP	YES	L4-L5	Conservative	N/A
	6	61/F	LBP + LLRP	N/A	L4-L5	Conservative	Partial relief
Yu Chen/2021	7	87/F	RLRP	YES	L5-S1	Surgery	Relief
Sugishima/2020	8	68/F	LLRP	YES	L4-L5	Surgery	Relief
Jin-Woo An/2018	9	73/F	LLRP	YES	L5-S1	Surgery	Relief
Bin Zhu/2017	10	57/F	RLRP	YES	L5-S1	Surgery	Relief
Hakan Cebeci/2016	11	55/M	LBP + LLRP	YES	L4-L5	N/A	N/A
Chul-Woo Lee/2014	12	68/M	LBP + LLRP	YES	L2-L3 L5-S1	Surgery + Interventional + Surgery	Relief
Jeon/2013	13	76/F	BLRP	YES	L4-L5	Surgery	Relief
A.H. ELBELTAGI/2013	14	51/M	BLRP	YES	L4-L5	N/A	N/A
Sang-Soo Kang/2012	15	68/M	LBP + RLRP	Operation	L5-S1	Interventional	Relief
Kyeong-Sik RYU/2012	16	72/F	LBP + RLRP	YES	L3-L4	Surgery	Relief
Chang-Hyun LEE/2012	17	76/M	LBP + LLRP/N	YES	L3-L4	Surgery	Relief
JunSeok BAE/2012	18	63/M	RLRP	NO	L2-L3	Surgery	Relief
SungMin Yun/2012	19	83/F	LBP + LLRP	YES	L4-L5	Surgery	Relief
	20	72/M	LLRP	YES	L5-S1	Surgery	Relief
Ambesi Impiombato/2011	21	85/M	LLRP	YES	L5-S1	Interventional	Relief
Hyung-Lea Cho/2011	22	80/F	BLRP	YES	L2-L3	Interventional + Surgery	Relief
HyunSook Kim/2011	23	67/M	SFD	NO	L5-S1	Surgery	Relief
Ali Akhaddar/2010	24	37/M	LLRP	N/A	L4-L5	Surgery	Relief
Dong Yeob Lee/2010	25	67/M	RLRP	YES	L2-L3	Surgery	Relief
Yousuke Kakitsubata/2009	26	57/F	RLRP	YES	L5-S1	Surgery	Relief
	27	72/M	RLRP	YES	L4-L5	Conservative	Relief
	28	73/M	LLRP/N	YES	L5-S1	Surgery	Relief
	29	51/F	RLRP	YES	L4-L5	Interventional	Relief
Akira Sei/2009	30	67/M	LBP + RLRP	YES	L2-L3	Surgery	Relief
Li-Jung Chiu/2008	31	71/M	RLRP	YES	L3-L4	Surgery	Relief
YOHEIKUDO/2008	32	51/M	LBP + LLRP	YES	L3-L4	Surgery	Relief
	33	66/F	LBP + RLRP	NO	L4-L5	Surgery	Relief
M. Sasani/2007	34	62/M	LBP + RLRP	Operation	L2-L3	Conservative	Relief
	35	72/M	LLRP	Operation	L4-L5	Interventional + Surgery	Relief
	36	74/M	RLRP	Operation	L3-L4	Conservative	Relief
	37	69/F	RLRP	Operation	L5-S1	Conservative	Relief
Deniz Konya/2007	38	51/F	NP	YES	C4-C5 C7-T1	Surgery	Relief
	39	65/F	N/A	Operation	N/A	Conservative	NO relief
	40	78/M	LBP + BLRP	NO	L4-L5	Conservative	Partial relief
ngel M. Hidalgo-Ovejero/2004	41	64/M	LBP	NO	L2-L3	Surgery	Relief
Yasuko Shima/2002	42	66/F	SFD	YES	C7-T1	Surgery	Relief
SATOSHI KAWAGUCHI /2001	43	60/F	LBP + RLRP/N	NO	L3-L4	Surgery	Relief
Harvey/2000	44	61/F	RLRP	NO	L3-L4	Surgery	Relief
Ronnie L/2000	45	70/F	LLRP	YES	L4-L5	Surgery	Relief
H. Yoshida/1997	46	65/F	LLRP	YES	L4-L5	Interventional	Relief
	47	69/M	RLRP/N	YES	L4-L5	Interventional	Relief
	48	61/M	RLRP	YES	L5-S1	Interventional + Interventional	Relief
I. G. Tobback/1992	49	70/F	RLRP	YES	L4-L5	Surgery	Relief
V. Bosser/1990	50	62/M	LBP + RLRP	YES	L4-L5	Interventional + Surgery	Relief
C. Kennedy/1990	51	49/M	N/A	Tumor	N/A	N/A	N/A

Table 1 (continued)

Authors/year	Patients	Age/gender	Presentation	Vacuum sign	Level	Treatment	Outcome
D. F. Fardon/1989	52	74/M	LBP + RLRP	YES	L4-L5	Surgery	Relief
R. Kumar/1989	53	64/F	LBP + LLRP	YES	L2-L3	Surgery	Relief

Abbreviations: F = female, M = male, LBP = low back pain, LLRP = left limb radiating pain, RLRP = right limb radiating pain, RHRP = right hand radiating pain, BLRP = bilateral limb radiating pain Bilateral, LLRM = left limb radioactive numbness, RLRM = right limb radioactive numbness, SFD = Sudden droop foot, NP = neck pain, N/A = not available

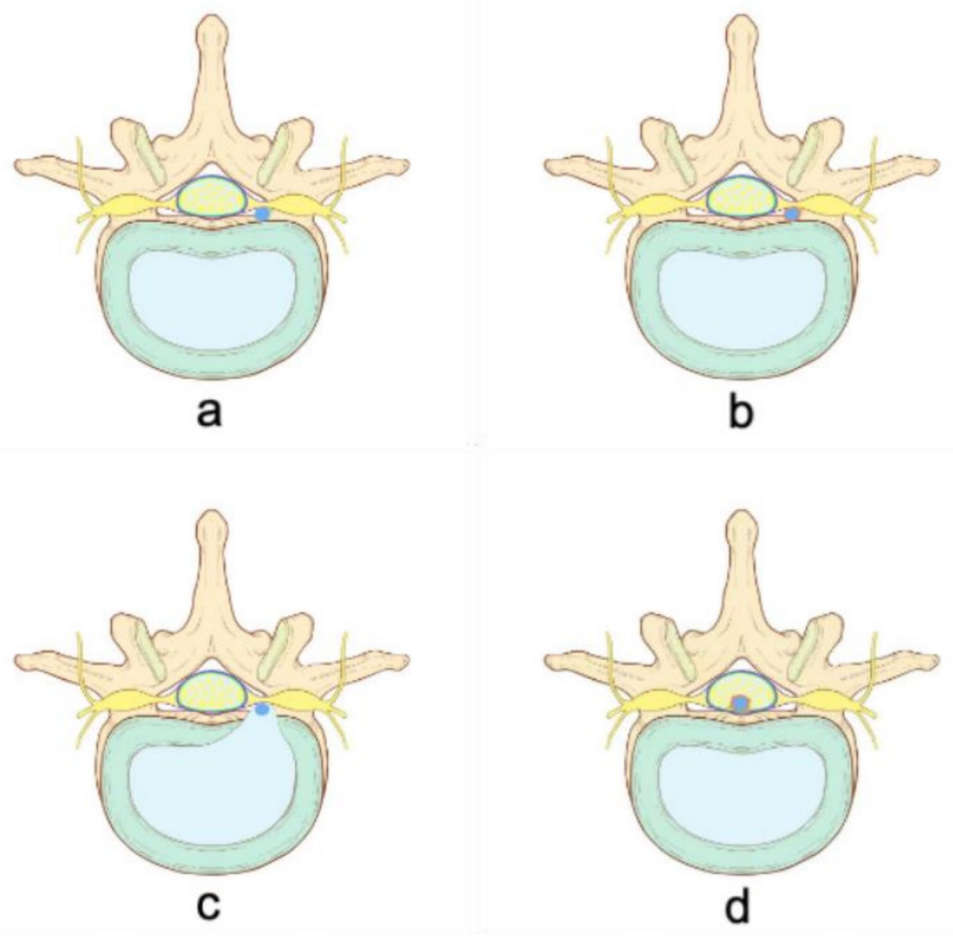

Fig. 2 (**a**) Type I: Pseudocyst as pure gas; (**b**) Type II: Air cyst as epidural gas with a thin cyst wall; (**c**) Type III: Air-contained disc herniation as epidural gas with disc herniation; (**d**) Type IV: Intradural type

Discussion

The causes of gas accumulation in the spinal canal are numerous, such as iatrogenic factors, trauma, tumors, and degenerative changes in the lumbar spine. It is noteworthy that gas accumulation in the spinal canal studied in this article pertain only to non-tumor patients with non-exogenous pathogenic factors. Accumulated gas substance that is in a gaseous or vaporous, state of matter. Gas is one of the four natural states of matter, along with liquid, solid and plasma. A gas has no fixed shape or volume. Previous reports have indicated that CT is an effective method for diagnosing gas accumulation in the spinal canal [3, 20, 30]. In this study, we included 40 studies with a total of 53 patients, classified the data based on the morphological characteristics of intervertebral disc and intraspinal gas on CT.

Gas accumulation in the spinal canal has been classified into two types in previous studies: extradural and intradural type. Extradural gas accumulation is supported by three theories [31–35]: (1) the vascular theory, which suggests that a hematoma formed within the dura after injury to the intradural venous plexus becomes encapsulated and subsequently leaves behind a cyst containing gas after hematoma absorption; (2) the degenerative theory, which proposes that protruding intervertebral discs gradually become encapsulated and form cysts; and (3) the accompanying theory, which suggests that gas is released into the spinal canal along with intervertebral

Table 2 Clinical characteristics of spinal gas accumulation

Type	Patient	Age (>60)	Gender (male)	Clinical manifestation			Level						Vacuum sign	Treatment			Intraoperative adhesion	Outcome (relief)
				LRP	LBP+LRP	Other	L1-L2	L2-L3	L3-L4	L4-L5	L5-S1	Other		Surgery	interventional	Conservative		
TypeI	34	25 (73.5%)	21 (61.8%)	19 (55.9%)	10 (29.4%)	5 (14.7%)	-	2 (5.7%)	4 (11.4%)	14 (40.0%)	12 (34.3%)	3 (8.6%)	22 (64.7%)	18 (52.9%)	7 (20.6%)	5 (14.7%)	3	28 (82.4%)
TypeII	7	6 (85.7%)	3 (43.9%)	4 (57.1%)	1 (14.3%)	2 (28.6%)	-	-	-	3 (43.9%)	2 (28.6%)	2 (28.6%)	7 (100%)	4 (57.1%)	2 (28.6%)	-	5	6 (85.7%)
Type III	3	2 (66.7%)	1 (33.3%)	-	1 (33.3%)	2 (66.7%)	-	-	1 (25.0%)	1 (25.0%)	-	2 (50.0%)	2 (66.7%)	2 (66.7%)	-	1 (33.3%)	0	2 (66.7%)
Type IV	9	8 (88.9%)	4 (44.4%)	4 (44.4%)	3 (33.3%)	2 (22.2%)	-	3 (33.3%)	4 (44.4%)	2 (22.2%)	-	-	5 (55.6%)	8 (88.9%)	-	-	4	9 (100%)

Abbreviations: LBP = low back pain, LRP = limb radiating pain

disc protrusion. Intradural pneumatosis is explained by two theories [36]: one involving congenital fusion between the dura and the posterior longitudinal ligament, and the other involving adhesions between these structures, possibly due to local inflammatory processes such as disc protrusion or previous surgery. We believe that adhesion between the dura and the posterior longitudinal ligament forms the structural basis of gas accumulation in the spinal, while the essence of the disease remains the entry of gas into the extradural or intradural space due to various causes. Therefore, this study includes both types of pneumatosis for investigation.

Extradural gas accumulation has been classified as air pseudocyst, air cyst, air-contained disc herniation, and honeycomb-like air cyst [1]. Pseudocyst is pure gas, air cyst is epidural gas with a thin wall, air-contained disc herniation is epidural gas with disc herniation, and honeycomb-like air cyst is disc herniation within multiple gas bubbles. They analyzed the relationship of image findings and clinical manifestation and found that lumbar epidural gas with disc material on MRI was associated with radiculopathy. However, the previous study did not analyze the adhesion between gas accumulation and dura, it can`t access the intraoperative risks of cerebrospinal fluid leakage. In the analysis of previous reports, we found that among the 7 patients with a marginally circular high-density type, 5 patients had adhesion during surgery, while only 3 of the 34 patients with a marginally non-circular high-density type had slight adhesion during surgery. We also found that among the 9 patients with an intradural type, 5 patients had enhanced MRI indicating high signal at the edge, and 4 patients had adhesion with the nerve root during surgery. We discovered this phenomenon in this systematic review, which suggests that surgical difficulties may be indicated based on preoperative imaging examinations.

We analyzed the relationship of CT images and intraoperative adhesion in the spinal gas accumulation patients and classified it into four types. The adhesion was not commonly found in type I and type III. Type I is the pure gas accumulation in the spinal canal, type III is the gas accumulation in the herniated disc, which do not cause adhesion.

Adhesion was commonly found in type II, which is the accumulation gas with a cyst wall. The CT value of gas is -1000 HU [3, 20, 30]. CT is very sensitive to changes in density, and locally increased density on CT usually indicates hematoma, calcification, tumor, and dense bands after inflammatory reactions. The gas composition in intraspinal gas accumulation is 92% nitrogen, oxygen, and carbon dioxide [37, 38]. Previous studies have shown that nitrogen can mediate and promote inflammatory reactions [39–41]. Histological examination of the cyst wall shows chronic inflammatory cell infiltration

Table 3 Air cyst as epidural gas with a thin wall

Patients	Age/Gender	Presentation	Vacuum sign	Level	Position	MRI	Treatment	Intraoperative adhesion	Postoperatively	Outcome
8	68/F	LLRP	YES	L4-L5	Facet joint	T2 Low signal, surrounded by high signal	Surgery	Adhesion	Fibrous tissue、bone and cartilage	relief
14	51/M	BLRP	YES	L4-L5	Facet joint	T2 Low signal, Enhanced mri enhancement of the wall cyst	N/A	N/A	N/A	N/A
28	73/M	LLRP/N	YES	L5-S1	Extreme lateral	T1 Low signal	interventional	Adhesion	N/A	relief
42	66/F	SFD	YES	C7-T1	Epidural	T2 Low signal, mixed high signal	Surgery	Adhesion	Fibrous tissue	relief
45	70/F	LLRP	YES	L4-L5	Facet joint	T1/T2 Low signal	Surgery	N/A	N/A	relief
48	61/M	RLRP	YES	L5-S1	Epidural	N/A	Interventional + interventional	Adhesion	N/A	relief
53	64/F	LBP + LLRP	YES	L2-L3	Epidural	N/A	Surgery	Adhesion	N/A	relief

Abbreviations: F = female, M = male, LBP = low back pain, LLRP = left limb radiating pain, RLRP = right limb radiating pain, BLRP = bilateral limb radiating pain Bilateral, LLRM = left limb radioactive numbness, RLRM = right limb radioactive numbness, SFD = Sudden droop foot, N/A = not available

[28]. The research indicates that intervertebral disc cells may immediately produce inflammatory cytokines/chemokines following intervertebral disc herniation, which may subsequently trigger macrophage infiltration and result in intervertebral disc degeneration [42]. In this study, it was found that there was high density around some low-density areas, and it was observed that adhesion was common in this type during detection. This leads us to speculate that the high density around the low-density area is related to intraoperative adhesions (TypeII). Although there is currently no physiological and pathological mechanism study on this phenomenon, due to the absence of reports of calcification, tumors, and blood clots during the operation, we are more inclined to believe that the dense band after inflammatory reaction, the inflammatory reaction between the fibrous cyst wall and the surrounding soft tissue, forms a denser adhesion area, also known as a dense band. This speculation needs further confirmation, but the classification provided by this phenomenon can indicate the difficulty of surgery for clinical physicians.

In the report by D'Andrea, the most common site of occurrence for type IV patients was L4-L5 [43]. In contrast, our study found that the distribution of affected segments in type IV patients was mainly in L2-L3 and L3-L4, accounting for 77.8% of cases. Based on our observations, CT diagnosis of intraspinal gas accumulation in intradural type patients is insufficient and requires enhanced MRI for further clarification. This is due to the characteristic ring enhancement observed on T1-weighted MR images enhanced with gadolinium-diethylenetriamine pentametric acid (GD-DTPA), which is caused by the vascularization of granulation tissue and intervertebral disc fragments surrounding the lesion. We also observed signs of cystic adhesion to the cauda equina during surgery in Type IV patients. Due to the dense adhesion between the cyst and the cauda equina, surgical treatment may be challenging. We speculate that this may be due to the degeneration of intervertebral disc components protruding into the dura mater and causing an inflammatory reaction, resulting in adhesion between the annulus, posterior ligament, dura mater, and cauda equina. This requires further research to confirm. However, not all patients exhibit signs of cauda equina adhesion, which may be due to the floating of the cauda equina. Whether the cyst entering the dura mater

Table 4 Intradural type

Patients	Age/Gender	Presentation	Vacuum sign	Level	Position	MRI	Treatment	Intraoperative adhesion	Postoperatively	Outcome
13	76/F	BLRP	YES	L4-L5	Intradural	T1/T2 Low signal	Surgery	Adhesion	Fibrous tissue	relief
22	80/F	BLRP	YES	L2-L3	Intradural	Enhanced mri Local high signal	Interventional + Surgery	No	Fibrous tissue	relief
30	67/M	LBP + RLRP	YES	L2-L3	Intradural	T1/T2 Low signal, Enhanced mri enhancement of the wall cyst	Surgery	Adhesion	Fibrous tissue	relief
31	71/M	RLRP	YES	L3-L4	Intradural	T1/T2 Low signal, Enhanced mri enhancement of the wall cyst	Surgery	No	Granulation tissue	relief
32	51/M	LBP + LLRP	YES	L3-L4	Intradural	T1/T2 Low signal, Enhanced mri enhancement of the wall cyst	Surgery	No	Fibrous tissue	relief
33	66/F	LBP + RLRP	NO	L4-L5	Intradural	T1/T2 Low signal, Enhanced mri enhancement of the wall cyst	Surgery	No	Fibrous tissue	relief
41	64/M	LBP	NO	L2-L3	Surgery	T1/T2 Low signal	Surgery	No	Cartilaginous disc fragment	relief
43	60/F	LBP + RLRP/N	NO	L3-L4	Intradural	T1/T2 Low signal	Surgery	Adhesion	Fibrous tissue	relief
44	61/F	RLRP	NO	L3-L4	Intradural	N/A	Surgery	Adhesion	Connective tissue	relief

Abbreviations: F = female, M = male, LBP = low back pain, LLRP = left limb radiating pain, RLRP = right limb radiating pain, BLRP = bilateral limb radiating pain Bilateral, LLRM = left limb radioactive numbness, RLRM = right limb radioactive numbness, N/A = not availabl

Table 5 Intraoperative adhesion of type

Type	Patients	Proportion	Treatment	Intraoperative adhesion
Type I	34	64.1%	25	Slight adhesion($n=3$)
Type II	7	13.2%	6	Adhesion($n=5$)
Type III	3	5.7%	3	No adhesion
Type IV	9	17.0%	9	Adhesion($n=4$)

adheres to the cauda equina is only a probability issue. As for the treatment of this type, simply removing the cyst is not sufficient. It is necessary to block the fistula and close the dura mater gap by suturing and adding fat, muscle, and human fibrin glue.

There are some limitations in this study. First, the surgical treatment of cases was performed by different doctors, leading to differences in intraoperative judgment and description. Second, the reviewers are familiar with the radiological features of intraspinal gas accumulation, which may result in differences during grouping. At last, due to the limited number of case reports and the need for more comprehensive imaging data, we only collected 53 cases of patients. We could only analyze t the trends in data between groups, but it does not have statistical significance. We did not find differences in clinical characteristics under this classification, as this requires a larger number of cases. Additionally, more cases are needed to further validate the relationship between the revealed imaging findings and intraoperative adhesions within this classification.

Conclusion

Gas accumulation in the spinal canal is a common Imaging phenomenon, which can be identified by CT and MRI, when the gas volume increases and causes clinical symptoms, the classification based on CT scans helps guide clinical treatment and improve surgeons` judgment of intraoperative adhesion.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13018-025-05895-w.

Supplementary Material 1

Supplementary Material 2

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Author contributions
All authors contributed to the manuscript. Study conception and design: WH, LW, JW; Acquisition and analysis of data: XC, QG, XX, WH; Methodology: WH; Funding acquisition: WH; Writing—original draft: XC, WH; Writing—review and editing: WH, JW.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval
Ethical approvals were obtained from the Ethic committee of 960 hospital of PLA (20200134).

Patient and public involvement
Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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