Lumbar plexopathy following instrumented posterior lumbar interbody fusion: a complication with use of Hohmann's retractor

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Abstract

Introduction A series of 12 patients in our centre following single level instrumented posterior lumbar interbody fusion at L4–L5 developed unexplainable motor weakness in the proximal lumbar nerve roots (L2, L3) and numbness of the whole limb, a clinical picture resembling lumbar plexopathy. Even though lumbar plexopathy has been reported following gynaecological procedures and in transpsoas interbody fusion surgeries, there is no literature reporting this complication following conventional instrumented posterior lumbar interbody fusions.

Study design Retrospective observational study.

Objective To find the possible mechanism of development of lumbar plexopathy in patients who underwent posterior lumbar interbody fusion surgeries in our centre.

Material and methods We analyzed retrospectively the medical records, electrophysiological reports of the patients, literatures on the anatomy of lumbar plexus and other literature reporting similar complications. We also dissected lumbar plexus of three cadavers and simulated surgical technique on them to find the mechanism of development of this unusual complication.

Results We found injury to lumbar plexus that probably occurred intraoperatively with Hohmann's retractor that was used for retraction of the paraspinal muscles. This theory was favoured by many clinical factors and further confirmed by cadaveric dissections.

Conclusion We conclude that surgical technique with improper use of Hohmann's retractor causes traction and compression injury to the lumbar plexus resulting in this complication. We propose proper technique of insertion of Hohmann's retractor and also recommend use of modified Hohmann's retractor with shorter tips for spinal procedures to prevent such complication.

Keywords Lumbar plexopathy · Instrumented posterior lumbar interbody fusion · Hohmann's retractor

Introduction

Lumbar plexus is situated within the posterior aspect of psoas muscle in front of the transverse process of lumbar vertebrae. It is formed by the anterior division of the first three and greater part of fourth lumbar nerves with a contribution from the last thoracic nerve. The branches arising from the lumbar plexus, their motor and sensory distribution is described in Fig. 1 and Table 1 [1].

Lumbar plexopathy has been described following radiation, trauma, neoplastic invasion, viral infection, diabetic amyotrophy and also idiopathic [2]. Post-operative lumbar plexopathy has been reported as a rare complication following gynecological procedures and surgeries involving retroperitoneal area like nephrectomy [3, 4]. In spinal surgery, lumbar plexopathy has been described following minimally invasive lateral transpsoas approach (LTIF) [5]. Even though meralgia parasthetica has been described in posterior lumbar interbody fusion (PLIF) surgeries, which is because of direct compression of lateral cutaneous nerve of thigh in prone position [6], there is no report of lumbar plexopathy following conventional instrumented PLIF (i-PLIF) in the literature. We report a series of 12 patients

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Fig. 1 **a** Anatomy of lumbar plexus and its branches, **b** sensory and motor distribution of the branches of lumbar plexus

Table 1 Sensory and motor distribution of branches of lumbar plexus

Nerve	Motor distribution	Sensory distribution
Iliohypogastric nerve	Branches to abdominal muscles	Lateral and anterior cutaneous branches supply skin over lateral aspect of hip, inguinal and pubic region
Ilioinguinal nerve	Branches to abdominal muscles	Skin over mons pubis, labia majora/scrotum
Lateral cutaneous nerve of thigh	No	Lateral aspect of thigh up to knee
Femoral nerve	Psoas muscle Iliacus Sartorius Rectus femoris Vastus lateralis, medialis and intermedius	Anterior cutaneous branch—anterior and medial thigh Saphenous nerve—infrapatellar branch—skin below patella Medial crural cutaneous branches—anterior and medial aspect of leg
Obturator nerve	Obturator externus Pectineus Gracilis Adductors of thigh	Medial aspect of thigh

who developed lumbar plexopathy following i-PLIF procedure in our center, the mechanism of its occurrence and possible prevention.

Materials and methods

We analyzed retrospectively medical records and various investigation reports like EMG/NCV studies of 12 patients who developed features of lumbar plexopathy following

i-PLIF between the months of July 2011 and April 2012, of the total 530 spine surgeries done during the same period. We reviewed the literature describing the anatomy of lumbar plexus and those reporting similar complications. We also dissected lumbar plexus in three cadavers and simulated surgical technique in them to find the etiology for this complication. Patients were examined on follow-up and those who were not able to attend the follow-up were enquired on phone regarding their symptoms and ambulatory status.

Results

The diagnosis, surgery done, age, sex, height, weight, duration of surgery, BMI, blood loss of the 12 patients analyzed are described in Table 2. Pre-operative and immediate post-operative neurological status of these patients is given in Table 3.

Some of the common findings among these patients on analyzing the medical records were—all patients had motor and sensory deficits proximal to the operated level, mainly the hip flexors, adductors and knee extensors which

represent L2 and L3 myotomes, respectively. Eleven of these patients had no motor weakness in the ankle and toes, while one patient showed weakness of ankle and toes in addition to proximal weakness. All cases were single-level i-PLIF surgeries at L4–L5 except one which was i-PLIF at L3–L4. None of the patient showed involvement of sacral roots, cauda equina or bladder and bowel abnormalities. Motor or sensory deficits were not confined to single nerve or root distribution. No case of L5–S1 PLIF or fusion surgeries involving vertebra higher than L3 developed this complication. There was no relation with age, sex, blood

Table 2 Details of the 12 patients who developed lumbar plexopathy

Case	Age	Sex	Surgery	Height (cm)	Weight (kg)	BMI	Side affected	Comorbidities	Duration of surgery (h)	Blood loss (ml)
Case 1	67	F	L4L5 PLIF	155	55	22.9	LEFT	HRSAG positive		
Case 2	65	M	L4L5 PLIF	147	50	23.1	LEFT	HTN	3.2	500
Case 3	36	M	PLIF L4L5	148	50	22.8	BOTH	NIL	4	1,200
Case 4	41	F	L4L5 PLIF	144	45	21.7	LEFT	NIL	2.5	500
Case 5	58	F	PLIF L4–5	149	52	23.4	LEFT	DM/HTN	3	200
Case 6	51	F	PLIF L4L5, PLIF L5S1	161	81	31.2	RIGHT	DM/HTN	3.4	300
Case 7	65	M	PLIF L4–5	160	80	31.3	RIGHT	NIL	3.3	600
Case 8	38	F	PLIF L4L5	149	71	32	LEFT	NIL	3	300
Case 9	51	M	PLIF L4L5	160	68	26.6	RIGHT	HTN	3	100
Case 10	61	M	PLIF L3L4	164	61	22.7	LEFT	NIL	3	300
Case 11	67	M	PLIF L4L5	162	60	22.9	LEFT	DM/HTN	4.3	300
Case 12	34	F	PLIF L4L5	160	75	29.3	LEFT	DM	3	

Table 3 Table shows PRE op and immediate post op neurological status of the patients

	Pre-op		Post op motor										Pre op motor											
			Right					Left					Right						Left					
	Motor	Sensory	L2	L3	L4	L5	S1	L2	L3	L4	L5	S1	L1	L2	L3	L4	L5	S1	L1	L2	L3	L4	L5	S1
Case 1	Normal	Normal	5	5	5	5	5	1	1	5	5	5	2	2	2	2	2	2	2	2	1	2	2	2
Case 2	Normal	Normal	1	1	5	5	5	1	1	5	5	5	2	2	2	2	2	2	2	2	2	2	2	2
Case 3	Normal	Normal	5	5	5	5	5	3	5	5	5	5	2	2	2	2	2	2	2	2	2	2	2	2
Case 4	Normal	Normal	5	5	5	5	5	2	3	5	5	5	2	2	2	2	2	2	2	2	1	2	2	2
Case 5	Normal	Normal	1	2	5	5	5	5	5	5	5	5	2	2	2	1	2	2	2	2	2	2	2	2
Case 6	Normal	Normal	2	2	5	5	5	5	5	5	5	5	5	2	2	2	2	2	2	2	2	2	2	2
Case 7	Normal	Normal	5	5	5	5	5	5	3	3	5	5	5	2	2	2	2	2	2	2	1	2	2	2
Case 8	Left L5–1	Left L5–1	2	4	5	5	5	5	5	5	5	5	5	2	2	2	2	2	2	2	2	2	2	2
Case 9	Normal	Normal	3	4	5	5	5	5	5	5	5	5	5	2	2	1	2	2	2	2	2	1	2	2
Case 10	Normal	Normal	5	5	5	5	5	5	4	4	5	5	5	2	2	2	2	2	2	1	1	1	2	2
Case 11	Normal	Normal	5	5	5	5	5	5	2	3	5	5	5	2	2	2	2	2	2	1	1	1	2	2
Case 12	Normal	Left L5–1	5	5	5	5	5	5	2	2	1	1	1	2	2	2	2	2	1	1	1	1	1	1

Grading of muscle power is done by MRC (Medical Research Council) grading with grade five being normal. Hip flexors, knee extensors, ankle dorsiflexors, long toe extensors and ankle plantar flexors are considered to represent L2, L3, L4, L5 and S1 myotomes while 2, 1 and 0 are considered as normal, impaired and absent sensations, respectively, as described by American spinal cord injury classification [10]

loss, duration of surgery, height, weight and BMI (basal metabolic index) of the patients. Six of these patients required knee brace and walker for ambulation, while two required walking stick and remaining four were ambulant without any aid. Most patients showed some recovery at the time of discharge.

Five patients were examined directly while six patients were interviewed on phone about their symptoms and ambulatory status at variable period of follow-up between 4 and 12 months. One patient was not contactable. At follow-up all patients were brace and walker-free ambulant. Three of the five patients examined directly showed complete motor and sensory recovery. One patient had complete motor recovery, but had persistent mild sensory deficit. One patient, who had both proximal and distal weakness, showed almost complete recovery of her hip and knee weakness but persistent distal weakness, at follow-up. Of the six patients interviewed over phone, four of them reported improvement while two patients reported status quo.

In the cadavers, while dissecting the lumbar plexus the genitofemoral nerve had to be sacrificed while reflecting the psoas muscle. Even though the exact measurements of distances of nerve roots from transverse process and vertebral body in cadavers may not accurately represent the actual measurements in the patients, we found the lumbar plexus was situated directly over the transverse process of vertebra with very little muscle fibers of psoas behind the plexus. Above L3 transverse process the L2 nerve root was situated medially close to L2 vertebral body, while just above L4 and L5 transverse process, the branches forming the femoral and obturator nerves progressively coursed away from the vertebral bodies. At the level of L4 vertebral body, femoral nerve was situated lateral to the vertebral bodies by about 1.5–2 cm. Anatomy of lumbar plexus on the cadaver dissected is shown in Fig. 2.

Fig. 2 Anatomy of the lumbar plexus as seen in the cadaver

Discussion

Based on the observations we made, we proposed several theories to explain the development of neurological deficits in the patients, like compression of femoral nerve at inguinal ligament on prone position, intra-operative insult to dural sac, retroperitoneal hematoma causing compression of lumbar roots, and so on. Compression of femoral nerve was ruled out as the deficits were not confined only to the distribution of femoral nerve. It was not seen in patients with long duration of surgeries and the deficits continued to occur even after providing adequate padding under the inguinal ligament. Dissection of the lumbar plexus revealed that the branches to psoas and iliacus were located proximal to the inguinal ligament and hence any compression to the nerves at the inguinal ligament would not cause hip flexor weakness. Intra-operative insult to the dural sac was also ruled out as majority of the cases did not have any difficulty in instrumentation, no obvious malposition of the implant was seen on post-operative X-rays and there was no involvement of nerve roots at the operated level or distally. In fact, one case had a CT scan done post-operatively, which showed proper positioning of the pedicle screws. Retroperitoneal hematoma causing compression of lumbar plexus was also ruled out by ultrasonography done in two of these patients.

On reviewing the literature and studying the anatomy, we realized that the deficits were due to involvement of lumbar plexus. On analyzing the surgical technique we found that the only instrument that was placed anterior to transverse process and lateral to vertebral body, close to the lumbar plexus, during the procedure was Hohmann's retractor. We proposed a hypothesis of Hohmann's retractor causing a traction and compression injury to lumbar plexus resulting in this complication (Fig. 3).

There were several factors which favored the above-proposed hypothesis. It explained the distribution of the motor and sensory deficits that was seen in our patients, majority of the patients showed recovery indicating it was compression or traction injury causing a neuropraxia rather than a direct injury to the nerves; EMG/NCV studies done in four of these patients were reported as lumbar plexopathy and moreover this complication ceased to occur once the using the Hohmann's retractor was stopped after proposal of this hypothesis.

Hohmann's retractor has been extensively used in orthopedic surgeries for retracting the muscle from bone. In our center, which is major center for spine surgery with about 600 spine surgeries done every year, Hohmann's retractor has been used since the last 12 years for retracting paraspinal muscles from the vertebra. Literature also describes the use of Hohmann's retractor for anterior, posterior and minimally invasive spine surgeries [7, 8].

Fig. 3 Hypothesis explaining the theory of Hohmann's retractor causing lumbar plexopathy. **a, b** Posterior and oblique views showing the technique of insertion Hohmann's retractor with the *tip* directed superiorly and laterally. **c, d** AP and oblique views after levering the retractor, showing compression and traction injury to the lumbar plexus caused by it

The measurements of a standard Hohmann's retractor used in our surgeries are described in Fig. 4. Although other centers have been using Hohmann's retractor in PLIF surgeries, this complication has not been reported.

Figure 5 shows the technique in which the Hohmann's retractor was used in PLIF surgeries in our center. After dissection of paraspinal muscles of the vertebral bodies, Hohmann's retractor is inserted at the junction of superior facet and transverse process and the muscles are retracted to facilitate screw insertion. The tip of the Hohmann's measures 25 mm. With the shoulder of the retractor resting on the transverse process, considering the thickness of transverse process at its base as 5 mm, at least 20 mm of the tip of Hohmann's retractor extends beyond the anterior surface of transverse process, reaching close to lumbar plexus. In our cadaveric dissection, we found that the lumbar plexus is situated immediately anterior to the transverse process, separated from the latter by a few muscle fibers. A similar cadaveric study by Lu et al. [9] also confirmed the close proximity of the lumbar plexus to the transverse process.

To further confirm the hypothesis, we inserted the Hohmann's retractor in the three cadavers in which lumbar plexus was dissected. Hohmann's retractor was inserted in all possible ways to find the mechanism which resulted in

injury to the lumbar plexus and also to find the safe method of using the retractor. Hohmann's retractor when inserted vertically downwards, passed medial to the nerve roots without damaging the roots. At L4 and L5 when the retractor was introduced at an angle with the tip directed superiorly and laterally, the tip of retractor went lateral to nerve roots which were located about 1.5–2 cm from vertebral body. When the retractor was levered, the nerve roots were pushed towards the vertebral body and were compressed between the retractor and vertebral body. It also pulled the proximally attached L2 nerve root causing a traction injury (Fig. 6).

Above L5 transverse processes, nerve roots forming the femoral nerve were situated lateral to vertebral body that allowed the Hohmann's retractor to push the roots by 1.5–2 cm medially against the vertebral body. The roots at this level were thicker and when combined with the obturator nerve provided a larger bulk of nervous tissue which allowed the Hohmann's to compress it against the vertebral body. Whereas, above L3 transverse process, L2 nerve root was found to be thin and lying close to the vertebral body. Consequently, when Hohmann's retractor was inserted lateral to it over L3 transverse process, L2 root was protected between the curve of the retractor and vertebral body (Fig. 7). Above L4 transverse a similar injury to the nerve

Fig. 4 Measurements of the standard Hohmann's retractor used in our surgeries. *Tip of the Hohmann measured 25 mm from the shoulders and had a smooth curve of 40° at 5 mm from the tip*

Fig. 5 Cadaveric showing the technique in which the Hohmann's retractor was used in our PLIF surgeries

roots occurred as seen at L5 transverse process, but to a lesser extent as the nerve roots here were less bulkier and situated less laterally.

From Fig. 7 it is evident that that the nerve most likely to be compressed by the retractor is the femoral nerve and the next common nerve being the obturator nerve. The branch from L4 root which joins the L5 to form

Fig. 6 Cadaveric specimen showing lumbar plexus being compressed by the tip of Hohmann's retractor

lumbosacral trunk and provides motor supply to the ankle dorsiflexors, is less likely to be affected. This probably explains the reason for involvement of L4 sensations but sparing the motor component of L4, i.e., the ankle dorsiflexors, in our patients. The anatomy of vertebral body was also a significant contributor to this complication. On studying the cross sections of the lumbar vertebral bodies in MRI, it was found that the posterolateral part of L5 vertebral body was flat whereas that of L3 was concave. Hence, nerve roots are more likely to be compressed

Fig. 7 **a** Cross section at L5 showing the Hohmann's being inserted over L5 transverse process with tip going lateral to the nerve roots, **A** part of femoral nerve formed by L2 and L3 roots, **B** branch of L4 root joining nerve **A** to form femoral nerve, **C** obturator nerve,

D branch of L4 root joining L5 to form lumbosacral trunk. **b** Hohmann's causing compression of the nerve roots against L5 vertebral body, **c** cross section at L3 showing the L2 root being protected between the body of vertebra and curve of the retractor

against the L5 body. Hypertrophied superior facet of L5 in degenerative L4/L5 spondylolisthesis, which pushes the Hohmann's retractor superiorly and laterally, is probably another contributing factor for this complication.

Based on these observations we defined 'the safe zones' for insertion of Hohmann's retractor which is less likely to result in injury to the lumbar plexus. These safe zones are located immediately lateral and superior to the superior facets. Whenever a Hohmann's retractor is used at L4 or L5 vertebra for retraction of paraspinal muscles, every attempt should be made to insert the Hohmann's in the safe zone and should always be directed medially and inferiorly to avoid damage to the nerve roots situated laterally. Lateral to the nerve roots, above L5 transverse process and to some extent above L4 transverse process is the 'unsafe zone'. Tip of the Hohmann's retractor when inserted in this zone is likely to damage the lumbar plexus. We also identified 'high risk points', which are located just below the lower margin of proximal transverse process medially. Hohmann's when inserted at these points vertically or directed superiorly may penetrate through the nerve roots causing direct damage to the roots, as was seen in our cadaveric study. These high-risk points should also be avoided while inserting the Hohmann's retractor (Fig. 8).

The use of Hohmann's retractor in lumbar fusions has been in practice in our center since almost 12 years. It has been used to retract paraspinal muscles from the facets to facilitate screw insertion. The reason for using it, apart from continuing the routine practice followed in our center, was that it provided good retraction of the paraspinal muscles with a small skin incision and because of the ignorance of the damage that the retractor caused to the lumbar plexus. The complication of weakness of hips and knees and numbness of limbs of varying severity has been encountered in our patients following lumbar fusions since last 12 years. However, it has been less frequent and has been neglected as it was thought to be a result of femoral

Fig. 8 Safe, unsafe zones and high-risk points to be considered while inserting the Hohmann's retractor

nerve compression from prone position and as many of these patients showed spontaneous recovery. Since last year, the complication became more frequent, which was probably because of more casual use of the Hohmann's retractor and needed some investigation to find the cause. The review of the medical records of the last 12 years would add some more cases to the series, but would be time consuming and not provide any further information to the investigation. Hence, only the cases during this period, when the complication was frequent were included in the study.

Even though the exact mechanism of what happens behind the muscle intraoperatively while inserting the Hohmann's retractor cannot be known, we proposed a hypothesis which possibly explained the etiology of neurological deficits that occurred in our patients, that was supported many factors as mentioned above. Based on these observations, we recommend not to use the Hohmann's retractor for lumbar spine surgeries. If at all a

surgeon prefers to use the Hohmann's retractor, the anatomy of the lumbar plexus, its relation with the lumbar vertebra, the safe zones, unsafe zones and the high-risk points should be kept in mind. Improper technique of using the Hohmann's retractor may result in damage to lumbar plexus. Alternatively, a modified Hohmann's retractor with tip <5 mm in length can be used safely to prevent such complications.

Conclusion

Hohmann's retractor when used improperly at L4 and L5 may result in lumbar plexopathy. This complication can be prevented by following the proper technique of insertion of the retractor, keeping in mind the anatomy of lumbar plexus and its relation with the lumbar vertebra.

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Conflict of interest None.

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