Original Article

An alternative way of C1 screwing: Supralaminar C1 lateral mass screws

ABSTRACT

Study Design: This study involves literature review, technical note, and case series.

Objectives: The objectives were to analyze indications and contraindications, advantages, and disadvantages for C1 lateral mass screw (LMS) insertion above or partially above the arch, to descript technical features, and to give examples of the practical application of this technique and investigated its safety.

Methods: A literature review was carried out in English and Russian in PubMed, Google Scholar, and eLibrary databases. We selected four patients, treated in our clinic, which was carried out partially supralaminar C1 LMS.

Results: Only three descriptions of supralaminar C1 LMS were found in the literature. Four adult patients underwent posterior C1–C2 screw fixation with C1 LMS along the superior edge of the C1 arch at our clinic. Partially supralaminar C1 screws were inserted on one of the sides due to the difficulties of using classical techniques. The main reasons for supralaminar screw fixation were narrow C1 lamina, hypertrophied venous plexus, and intraoperative failures of classic techniques application (broken screw trajectory, profuse venous bleeding from the plexus). The average follow-up time for the patients was 2.7 years, no complications were noted, and all had a satisfactory spinal fusion.

Conclusions: The proposed types of C1 LMS above or partially above the C1 arch can be useful alternative method of C1 screwing in selected patients. Indications for the use of the supralaminar C1 LMS method can be narrow C1 posterior arch and pedicle, pronounced C1-C2 venous plexus, some V3 segment anomalies at C1 level, small arthritic inferior part of lateral mass, and intraoperative failures of classic techniques application.

Keywords: Alternative C1 screw, C1 lateral mass screw, C1 screw above arch/lamina, LMS, superior part of lateral mass, superior part of C1 lateral mass, supralaminar C1 screw

INTRODUCTION

The C1 vertebra is an important reference point for screws in C1–C2 spondylodesis, occipitospondylodesis, and multilevel posterior cervical spondylodesis. Goel and Laheri in 1994 proposed a method of C1 lateral mass screws (LMS) fixation that completely changed the view on the treatment of pathology in the C1–C2 region.[1] This method solved several problems at once: first, it "shortened" the length of instrumental fixation (there is no need to fuse the occiput); second, this method allows the surgeon to create levers for C1 reposition; and third, it provides a more rigid fixation than hooks, cables, or wire.[1]

Standard techniques of C1 screwing are pedicular, sublaminar, or partially sublaminar (lower part of C1 lateral mass).[2] Each method has its own advantages and disadvantages. In

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some cases, these techniques are difficult to implement or inapplicable. Some contraindications for classic C1 screwing are C1 posterior lamina hypoplasia, narrow C1 pedicle, hypertrophied venous plexus, arteries position at the site of lower part of C1 lateral mass, and intraoperative failures of classic techniques application.[3]

The most famous alternative methods of C1 screw fixation are intralaminar (laminar) C1 fixation, occipitospondylodesis (expansion of the fixation zone to occiput), C1 cables,[4] C1 laminar hooks, and wires.

The screw insertion over the C1 arch into lateral masses is poorly described in the literature only for congenital V3 segment of vertebral artery (VA) anomalies. The purpose of our work was to analyze indications and contraindications and advantages and disadvantages for this technique. We also provided a description of it and gave examples of the practical application of this technique and investigated its safety.

METHODS

The literature review was carried out in English and Russian in PubMed, Google Scholar, and eLibrary databases. Search queries were supralaminar C1 lateral mass screw, alternative C1 screw, and C1 screw above arch/lamina.

We selected four patients treated in our clinic at 2016–2019 year. The selection criteria were the following: partially supralaminar C1 lateral mass screwing, age over 18 years, and follow-up period 2 years or more. All patients underwent preoperative magnetic resonance imaging, preoperative and postoperative X-rays and computed tomography (CT). The analysis includes etiology of the pathologic process, clinical status (preoperative and postoperative visual analog scale and modified by Benzel Japanese Orthopaedic Association scale (mJOA)), features of surgery (duration, blood loss), features of individual anatomy (the distances from the occipital bone to the C1 arch and from C1 arch to VA, the height of the lateral mass above the arc, at the level of the arc and under the arc, external and internal pedicles thickness), and outcomes.

RESULTS

Literature review

We found only a few descriptions of supralaminar C1 lateral mass screw fixation in the literature. Hong *et al*. described the use of screw fixation in the upper part of the side mass C1 (superior lateral mass) in five patients with traumatic (three cases) and congenital (one case) pathology due to the presence of a V3 segment anomaly.[5,6] All patients were adults, no complications occurred. Yi *et al*. analyzed the risk factors of posterior C1 lateral mass screw fixation in 180 patients,[7] three of which underwent supraliminal C1 screwing. Complications were also not identified.

Patient's data

Four patients underwent posterior C1–C2 screw fixation with C1 LMS along the superior edge of the C1 arch [Tables 1 and 2]. Two patients had old odontoid fracture, one rheumatoid arthritis C1–C2, and one degenerative C1–C2 osteoarthritis.

Table 3 presents the following radiological parameters: the distances from the occipital bone to the C1 arch (Oc-C1) and from C1 arch to VA (C1-VA), the height of the lateral mass above the arc (superior part of lateral mass [SLM]), at the level of the arc (middle part of lateral mass) and under the arc on both sides (inferior part of lateral mass-[ILM]), and external and internal pedicles thickness [Figure 1]. The average distance from the occipital bone to the C1 arch was 9 mm; from the C1 arch to the VA, it was 2.3. These data indicated that there was sufficient reserve space for the VA dissection and displacements, taking into account that the screw diameter was 3.5 mm. In all patients, on the side of the supralaminar screw implantation, the C1 vertebral arch had a thickness $\leq$4 mm.

C1–C2 screwing with spondylodesis was performed in all four patients. Partially supralaminar C1 screws were inserted on one of the sides due to the difficulties of using classical techniques [4 screws, Figure 2]. The main reasons for supralaminar screw fixation were narrow C1 lamina, hypertrophied venous plexus, and intraoperative failures of classic techniques application (broken screw trajectory, profuse venous bleeding from the plexus).

The average follow-up time for the patients was 2.7 years [Table 1], no complications were noted, and all had a satisfactory spinal fusion.

Technical note

Surgeries were performed under general anesthesia in the prone position, with a head fixed in a Mayfield head holder. Standard midline incision and subperiosteal dissection of paraspinal muscles was made to expose the occipital squama, posterior C1 arch, and C2 lamina. The occipital squama and C1 arch were dissected approximately 20 mm lateral to the midline. The VA was identified coursing along its groove and it was dissected cranially away from the groove (using microscope or loupe). The loop was retracted superiorly until the posterior surface of C1 LM is rendered.

Two penfield dissectors are placed above and under the edges of the C1 arch approximately in the middle in the area of the entrance to the C1 lateral mass for VA (above) and venous plexus (under) protection. An entry point on the upper edge

Table 1: Preoperative patient's data

Number	Age, gender (years)	Pathology	VAS	mJOA	Contraindications to classical C1 screwing
1	Аверин 49-year-old male	Trauma	5	18	Narrow C1 lamina, hypertrophied venous plexus, broken screw trajectory
2	Корчина 66-year-old female	Reumatoid	8	16	Narrow C1 lamina, hypertrophied venous plexus, broken screw trajectory
3	Никитина 71-year-old female	Degenerative	8	15	Narrow C1 lamina, small left ILM, hypertrophied venous plexus, broken screw trajectory
4	Глухов 29-year-old male	Trauma	5	14	Narrow C1 lamina, hypertrophied venous plexus, broken screw trajectory

ILM - Inferior part of lateral mass, VAS - Visual analog scale, mJOA - Modified be Benzel Japanese Orthopedic Scale

Table 2: Postoperative patient's data

Number	Age, gender (years)	C1 screws	Surgery duration (min)	Blood loss (ml)	Follow-up (years)	Post VAS	Post mJOA
1	**Аверин** 49-year-old male	1 PILM right 1 PSLM left	95	100	3.4	1	18
2	Корчина 66-year-old female	1 PILM left 1 PSLM right	140	50	2.1	2	18
3	Никитина 71-year-old female	1 PILM right 1 PSLM left	170	150	3.2	3	17
4	Глухов 29 year old male	1 PILM left 1 PSLM right	175	60	2.0	1	17

PILM - Partially et inferior part of the lateral mass (sublaminar), PSLM - Partially et superior part of the lateral mass (supralaminar), VAS-- Visual analog scale, mJOA - Modified be Benzel Japanese Orthopedic Scale

Table 3: Morphometry of C1 occiput vertebral artery relationship and C1 posterior structures

Number	Age, gender (years)	Oc-C1 mm		VA-C1 mm		SLM mm		MLM mm		ILM mm		EPW mm		IPW mm	
		Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
1	Аверин (PSLM left) 49-year-old male	8.9	7.8	4.4	1.0	6.6	6.7	7.3	7.6	6.5	9.0	4.0	6.2	2.2	3.0
2	Корчина (PSLM right) 66-year-old female	8.8	10.1	1.3	1.5	7.9	8.1	2.9	3.3	4.5	4.9	2.1	1.6	0	0
3	Никитина (PSLM left) 71-year-old female	7.5	7.7	1.8	4.3	8.5	6.9	2.3	4.1	4.5	6.3	2.0	3.6	0	1.5
4	Глухов (PSLM right) 29-year-old male	9.1	11.9	2.0	2.0	7.1	5.6	7.1	6.0	8.7	8.6	6.3	4.0	2.4	1.2

Oc-C1 - Distance from the occipital bone to the C1 arch, VA-C1 - Distance from C1 arch to the vertebral artery, SLM - superior part of lateral mass, MLM - Middle part of lateral mass, ILM - Inferior part of lateral mass, IPW: Internal C1 pedicle width, EPW: External C1 pedicle width

of the posterior arch of the atlas, 4 mm laterally to the medial surface of the lateral mass, is then chosen. The lateral mass was then perforated using a hand-held drill under X-ray control, a probe was used to explore the walls of the hole. The trajectory was approximately 0°–5° in the medial direction and 0° in the cephalad direction. The optimal direction of the trajectory was individual, depending on the preoperative measurements and intraoperative anatomy. Then, the hole was tapped and a 3.5 mm screw was inserted (screw length: 26–30 mm). The screws were inserted taking care to leave enough space between the screw head and the occipital squama for the VA.

We recommend using partially threaded screws in such cases. If the screw is fully threaded, it is necessary to lay a nonabsorbable gasket between the screw and the VA (autofascia for example).

All screws were implanted using the freehand technique; however, the use of computer navigation and intraoperative ultrasonography may increase the safety of operation.

All operations were performed by the author of the paper: A. V. Burtsev and A. V. Gubin.

Fully supralaminar C1 LMS are suitable for use in V3 segment anomaly when the vessel above the C1 pedicle is absent, in this case, there is no need for dissection and mobilization of the artery above the arch [Figure 3].

DISCUSSION

Classical C1 screwing

Three standard methods of C1 LMS insertion are described: The introduction of the screw is through the arch (pedicle

Figure 1: Measurement of the main parameters on preoperative computed tomography [Table 3]: Oc-C1 – distance from the occipital bone to the C1 arch, VA-C1 – distance from C1 arch to vertebral artery, SLM – height of the lateral mass above the arch, middle part of lateral mass – height of the lateral mass et the level of the arch, inferior part of lateral mass – height of the lateral mass under the arch, EPD – external C1 pedicle diameter, IPD – internal C1 pedicle diameter

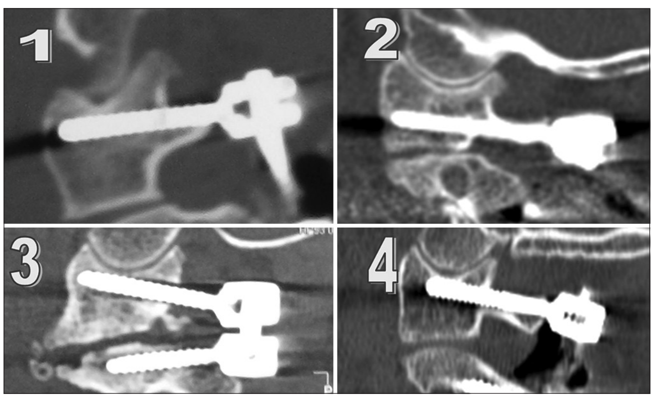

Figure 2: Postoperative computed tomography of implanted supralaminar C1 lateral mass screws (patients are numbered according to positions in tables)

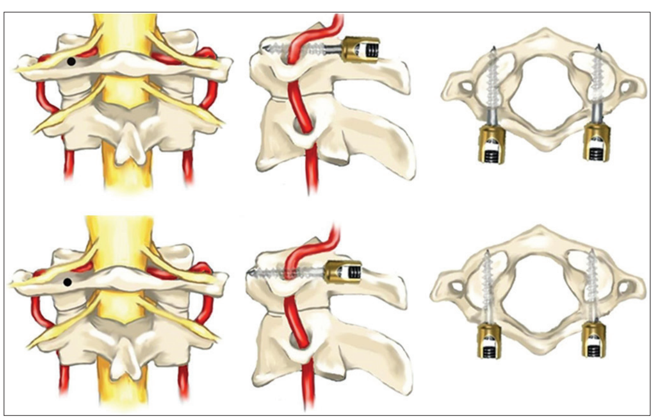

Figure 3: Schematic representation of C1 lateral mass screwing techniques over the arch (upper row) and partially over the arch (bottom row)

screws), under the arch (sublaminar, clearly LMS), and along the lower edge of the arch (partly under the lamina posterior).[1,2,8] The choice of technique depends on the individual anatomy of the C1 vertebra (the height and width of the arch, pedicles, depth of the VA sulcus, the size of the lateral masses, and the presence of anomalies) and vessels anatomy (V3 segment, posterior inferior cerebellar artery, and C1–C2 venous plexus).

In cases of sublaminar and partially sublaminar C1 LMS, there is risk of profuse bleeding from venous plexus and C2 root damage.

The C2 root passes along the posterior surface of C1–C2 joint, and implantation of the screw in this area can cause persistent postoperative pain associated with irradiation along the root.[7,9,10] A number of authors recommend cutting the root to prevent this complication; this manipulation can reduce bleeding and shorten the operation time. At the same time, the risk of chronic occipitalgia remains; in addition, persistent numbness in the occipital region is formed in a greater number of cases.

C1 pedicle screws are considered the most mechanically correct method since it is allowed to implant a longer screw. This option is useful in deformity surgery or in patients with severe osteoporosis in whom purchase of LMS may be questionable. The main problem for use C1 pedicle screw is the risk of VA injury due to the narrow pedicle or arch and deep VA groove.

The reported incidence of the VA injury with C1–C2 screw fixation ranges from 1.7% to 5% in the reported literature.[7] Narrow C1 lamina/pedicle can lead to VA injury (if the VA is not visualized and mobilized and the screw is inserted “blindly”).[11-13] Most experts believe that the thickness of the C1 arch/lamina in the area of pedicle screw implantation <4 mm is a risk factor for VA injury. According to morphometric studies in various populations of adults, from 19.2% to 53.8% had narrow C1 pedicle (<4 mm),[2,8,13,14] 49% had internal pedicle diameter <1 mm, and 38% had no intramedullary canal.[12] The average C1 pedicle thickness in women lesser than in men.[12]

Alternative C1 screwing

C1 cables,[4] wires, and hooks[15] are widely described alternative C1–C2 fixation techniques. They have the following disadvantages: mechanical instability, high frequency of fusion failure, narrowing of the spinal canal width, and impossibility of performing C1 laminectomy. These techniques are difficult to perform in the presence of a C1 spina bifida. The C1 locking plate, described by Kelly *et al*., may be a viable alternative with decreased surgical risk,[16] but it did not get distribution.

Unilateral or crisscrossing intralaminar (laminar) C1 screws are one of the alternative C1 screwing methods that are attracting a lot of attention at present time.[17-21] Its disadvantages are needs for a certain thickness of the C1 arch, impossibility of bone decompression if necessary (laminectomy), as well as the difficult connection of screws. This method is difficult to perform in patients with C1 arch hypoplasia or with C1 spina bifida posterior.

Occipital plating (skipping C1 vertebra) is also one of the ways to fix the upper cervical spine in case of C1–C2 pathology. The atlanto-occipital joint is very tight and the movements in this segment are not wide, which makes it possible in some cases to prolong the fixation to occiput when C1 screw fixation is difficult.

Supralaminar C1 lateral mass screw (upper lateral mass screw)

Individual anatomical features of the craniovertebral junction allow safe supralaminar C1 LMS screw fixation in selected patients.

According to research by Blagg *et al*., the average height of posterior lateral mass superior to arch (SLM) in adults is 4 mm, the average height of posterior lateral mass at level of arch is 4.5 mm, and the average height of posterior lateral mass inferior to arch (ILM) is 4.5 mm.[22] Despite the limited height of the upper part of the lateral mass, occipital condyle (the average height: 9–11 mm) creates additional space for VA displacement.[23-25] Morphological studies of the C1 region revealed that the average diameter of the V3 segment is 3.7 mm.[3] The undulating course of the VA creates a reserve of length for free neck movements, this feature also contributes to its tension-free displacement during surgery.

Since when performing C1–C2 fusion, rotational movements in the segment are excluded, the corresponding risk of VA compression by the construction is also reduced providing free movement during rotational movements of the neck.

In case of V3 segment anomalies of the VA, with the latter passing under the posterior arch of C1, classic LMS insertion is difficult to do.[6,7,26,27] In these cases, C1 LMS implantation into the upper part of the lateral mass becomes possible. According to literature data, V3 segment anomaly occurs in 0.5%–30% generally, and VA anomalies on C1 level occur in 5%–10% patients.[3,28] The risk of such anomalies is higher in patients with congenital malformations and atlantoaxial subluxations.[28]

Indications for the use of the supralaminar C1 LMS method can be narrow C1 posterior arch and pedicle (<4 mm), pronounced C1–C2 venous plexus, some V3 segment anomalies at C1 level (vessel in the ILM area), small arthritic ILM, and intraoperative failures of classic techniques application (broken screw trajectory and profuse venous bleeding from the plexus).

CONCLUSIONS

Currently, there is a wide range of techniques for C1 instrumental fixation. This allows an individual approach to each patient, based on the features of his anatomy and the nature of the pathology.

The proposed types of C1 LMS above or partially above C1 arch can be a useful alternative method of C1 screwing in selected patients.

Indications for the use of the supralaminar C1 LMS method can be narrow C1 posterior arch and pedicle, pronounced C1–C2 venous plexus, some V3 segment anomalies et C1 level, small arthritic ILM, and intraoperative failures of classic techniques application.

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Conflicts of interest

There are no conflicts of interest.

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