Endoscopic Endonasal Approaches to the Clival Region

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Received: 28 April 2020; **Accepted:** 8 September 2020

Abstract

Objective. Our main objectives were to analyze and determine the safety, risk of post-operative complications, and surgical outcome of the endoscopic endonasal approach to the clival region. **Methods**. From May 2011 to May 2019, we operated on 19 patients using the endoscopic endonasal approach to the clival region. Their pathologies were diverse: pituitary macroadenoma, craniopharyngioma, metastasis, and a prepontine neurenteric cyst. The first operations were supervised by an experienced center using telementoring. We explained our surgical technique and analyzed the patients' data, which were included in our study. **Results.** We managed to achieve complete removal of the pathological process in 14 patients. There were no deaths in the perioperative and early post-operative period. The most common complication was a cerebrospinal fluid leak, which was successfully managed in all of the cases. There were no deaths or significant morbidities in the post-operative period. **Conclusion.** An endoscopic transnasal approach to the clival region is safe and effective. It provides better visualization of that region compared to other transcranial approaches. The risk of post-operative complications is significantly lower with the help of modern reconstructive techniques. CSF leak is the most frequent complication.

Key Words: Endoscopic Endonasal Approach ▪ Clival Region ▪ Operational Technique ▪ Complications ▪ Differential Diagnosis of Clival Pathology.

Introduction

The posterior cranial fossa, especially the clival region, is in the skull base, which is often difficult to access surgically (1). Managing clival lesions presents numerous challenges due to the close proximity of surrounding critical structures, including the basilar and internal carotid arteries, brain stem, and the cranial nerves (2). Important region considerations are the depth of the surgical approach and the effect of the tumor on the surrounding structures (3-6). The endoscopic endonasal approach has recently become one of the most frequently used methods in the surgical management of clival lesions at leading skull base centers (7-10). With the help of the endoscopic endonasal approach, operating procedures in the clival region have become safer, faster, and easier to perform, compared to transcranial methods.

The development of endoscopic endonasal surgery for different pathologies in the skull base region has made significant progress in the last 10 years. Skull base regions are more accessible with the help of the extended endonasal approach, especially the clival region. The endonasal approach to this region is faster and safer than transcranial techniques. It provides a direct view of the median structures of the skull base without applying traction to various structures of the brain (3-6). Surgical telementoring from experienced centers is able to provide considerable help in achieving a higher level of surgical proficiency (11).

With the help of modern reconstructive techniques, the rate of post-operative complications

is lower, especially cerebrospinal (CSF) leak (12). The results of the endoscopic endonasal approach to the clival region may thus be equal or superior to the results of transcranial approaches (1).

The most common lesions involving the clival region are: chordomas, chondrosarcomas, meningiomas, pituitary adenomas, metastatic tumors, and plasmacytomas. The first endoscopic endonasal approach to the clival region for these diverse pathological processes for our institution, the University Medical Center, Maribor, was performed in May 2011. All operations were performed with a collaborating team of ear-nose-throat (ENT) specialists and neurosurgeons. Surgical telementoring from the University of Pittsburg Medical Center was utilized in the first two years when performing complex endonasal procedures. This paper presents our results in the 8-year period.

Our main objectives were to analyze and determine the safety, risk of post-operative complications, and surgical outcome of the endoscopic endonasal approach to the clival region.

Methods

Surgical Technique

All patients underwent surgery using the extended endoscopic endonasal approach (EEA). Two surgeons (a neurosurgeon and an otorhinolaryngologist) cooperated throughout the procedure. Two nostrils were used to insert the endoscope and surgical instruments throughout the procedure. The leading surgeon was determined on the basis of the stage of the procedure. To start with, we prepared the nasoseptal flap on one side of the nose and performed complete ethmoidectomy with a median meatotomy. We saved the flap in the maxillary sinus and continued the approach with posterior septectomy (resection of the vomer) and bilateral sphenoidotomy. We saved the epithelial tissue of the nasal septum on the opposite side for reconstruction of the remainder of the nasal septum. We proceeded with the removal of epithelial tissue of the sphenoid and posterior ethmoidal sinuses, and the complete resection of the rostrum. We resected the epithelial tissue of the nasopharynx when nec-

essary. With the resection of the clivus, we created a corridor between both paraclival carotid arteries. We drilled the bone until we reached the basilar plexus. Bleeding in this region was usually stopped with liquified hemostatic materials. After complete hemostasis, we proceeded from the extradural to the intradural stage of the operation in cases where the pathology lay subdurally.

The intradural technique of tumor removal was the same as the usual microscopic technique. The only difference was that it was performed with endoscopic visualization. The instruments were longer and modified for the endoscopic approach. Resection of critical structures demanded good cooperation between the two surgeons. We had to maneuver the location and angles of the endoscope to achieve the best possible visualization of critical structures. When bleeding occurred, coagulation was possible with the use of a modified coagulator. Applying sutures using endoscopic techniques was especially challenging. We used 5-0 nylon interrupted sutures. It was found that interrupted sutures were more suitable for a tight dural closure than running sutures, which were technically harder to place. Some authors did not use sutures at all, but use fibrin glue and mucosal flaps instead (13). Others, such as Yudo et Al., used a technique similar to ours (14). To achieve hemostasis, we sometimes used miniature surgical staples.

We then proceeded with the multi-layered reconstruction of the defect. For the intradural avascular layer, we used fascia lata. The second avascular layer was placed extradurally. It covered the defect and the surrounding bone. Resection of the clivus created a deep defect in the bone, which we filled with autologous fat from the patient's thigh. We then covered the avascular reconstruction with the vascularized nasoseptal flap, which we had prepared earlier on. The flap covered the entire avascular reconstruction and the resected bone, from which we removed all the epithelial tissue. Patients with more severe clival defects required the insertion of a lumbar drain and the opening of the prepontine cistern.

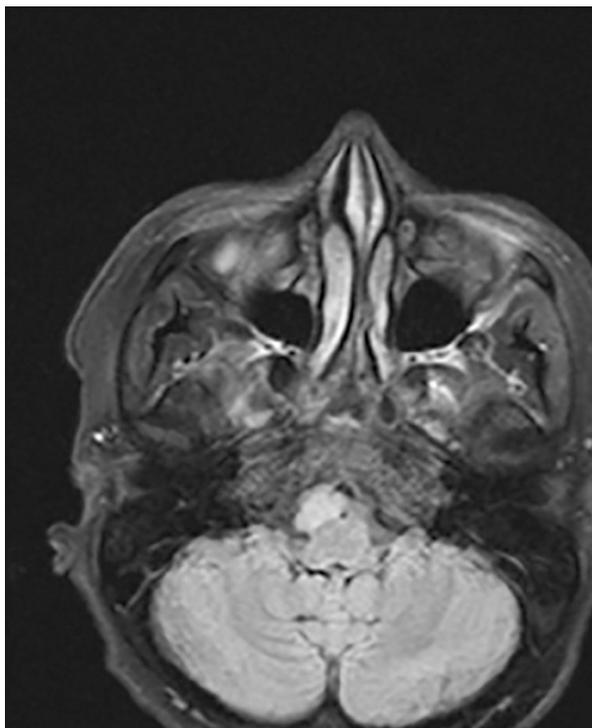The case of one patient with an intradural lesion is presented in Figures 1-3.

Figure 1. Preoperative head MRI of a 48-year old female patient with right abducens nerve palsy and a neurenteric prepontine cyst. The cyst was removed entirely and the abducens nerve palsy normalized.
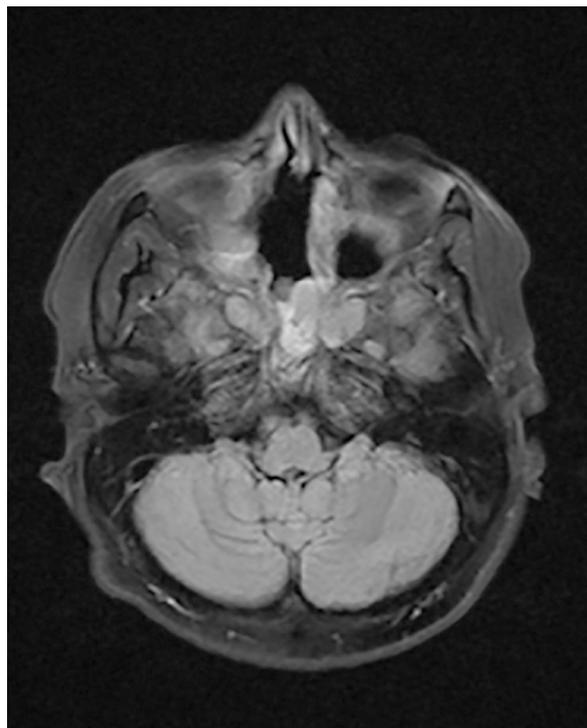

Figure 3: Post-operative head MRI of the patient presented in Figure 1, showing the completely removal of the prepontine cyst.

Results

Patients

From March 2011 to May 2019, we operated on 19 patients (10 females, 9 males). The average age of the patients was 52 years (standard deviation of 15 years). Nine patients had pituitary macroadenoma (6 of them had a secreting tumor with acromegaly, 3 of them had non-secreting tumors). In all of them the pituitary tumor invaded the clivus. Other pathologies were less frequent. Patients' characteristics, surgical variables, outcomes and complications are summarized in Table 1.
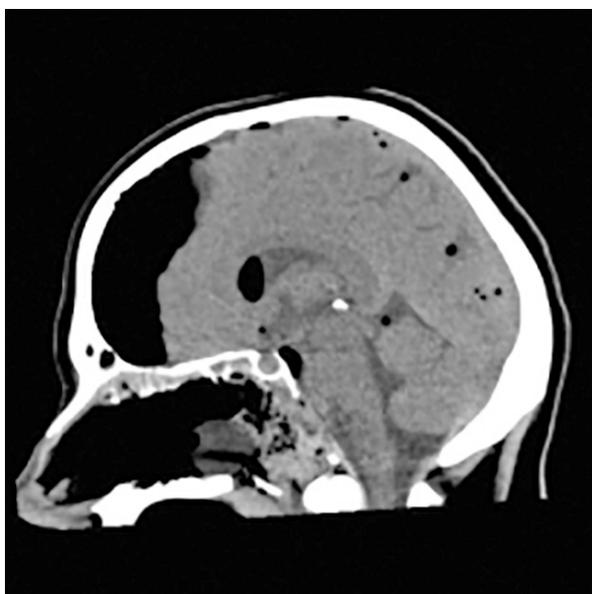

Figure 2. Post-operative head CT of the patient presented in Figure 1, which was taken on the first post-operative day. Most of the clivus has been resected due to the approach to the cyst. Pneumocephalus is seen, which did not manifest clinically and later spontaneously resolved.

Table 1. Patients' Characteristics

Patient	Gender	Age (year)	Pathology	Type of resection	Reconstruction	Outcome	Death[*]	Intradural growth	Dural opening	Complications
1	M	40	Pituitary adenoma (secreting tumor)	Complete removal	Multilayer	Following up	No	No	No	-
2	F	53	Pituitary adenoma (secreting tumor)	Complete removal	Multilayer	Following up	No	No	No	-
3	M	37	Pituitary adenoma (secreting tumor)	Complete removal	Multilayer	Following up	No	No	No	-
4	F	64	Pituitary adenoma (secreting tumor)	Complete removal	Multilayer	Following up	No	Yes	Yes (1 cm)	CSF leak
5	F	66	Pituitary adenoma (secreting tumor)	Subtotal resection	Multilayer	Following up	No	Yes	No	-
6	M	68	Pituitary adenoma (secreting tumor)	Complete removal	Multilayer	Following up	No	Yes	Yes (1 cm)	-
7	M	64	Pituitary adenoma (non-secreting tumor)	Subtotal resection	Multilayer	Following up	No	Yes	Yes (1.5 cm)	CSF[†]
8	F	48	Pituitary adenoma (non-secreting tumor)	Complete removal	Multilayer	Following up	No	No	No	-
9	F	64	Pituitary adenoma (non-secreting tumor)	Subtotal resection	Multilayer	Following up	No	No	No	-
10	M	49	Chordoma	Partial resection	Multilayer	Died 1 year after surgery	No	Yes	Yes (2 cm)	-
11	M	44	Chordoma	Complete removal	Multilayer	Following up	No	No	No	-
12	F	68	Chordoma	Subtotal resection	Multilayer	Died 3 years after surgery	No	No	No	Bleeding[‡]
13	F	38	Chordoma	Complete removal	Multilayer	Following up	No	No	No	-
14	M	67	Metastasis (origo prostate cancer)	Complete removal	Multilayer	Died 1 year after surgery	No	No	No	-
15	F	58	Metastasis (origo breast cancer)	Complete removal	Multilayer	Died 1 year after surgery	No	No	No	-
16	M	61	Craniopharyngioma	Complete removal	Multilayer	Following up	No	Yes	Yes (3 cm)	Bleeding[§]
17	F	48	Neurenteric cyst	Complete removal	Multilayer	Following up	No	Yes	Yes (2.5 cm)	-
18	M	45	Solitary fibrous tumor	Complete removal	Multilayer	Following up	No	Yes	Yes (3 cm)	CSF[†]
19	F	6	Cholesteatoma	Complete removal	Multilayer	Following up	No	No	No	-

[*]Perioperative or Postoperative period; [†]CSF leak, revision surgery, [‡]Minor post operative bleeding; [§]Bleeding continued with procedure one week later.

None of our patients died in the perioperative or early post-operative phase. One patient with chordoma died one year after the operation because of disease progression, while one patient died three years after the procedure due to myocardial infarction. Two patients with metastatic disease died one year after the operation because of the progression of the primary disease. The rest of the patients are still alive and are being followed up with regular MRI scans and hormone testing if necessary. Acromegaly has been well controlled after the surgery in six patients, where three of them need additional medical therapy. We achieved complete removal (no evidence of tumor tissue on postoperative CT or MRI scan) of the pathological process in 14 patients. One patient with chordoma had partial resection using the endoscopic transnasal approach, while the rest of the tumor in the pontocerebellar angle was removed using the suboccipital retrosigmoid approach. Subtotal removal (the volume of the remaining tumor tissue is less than 20% of the original tumor size) in the remaining 4 patients, one with chordoma and three with pituitary adenoma. The most common reason for subtotal removal was adherence of the tumor to the surrounding vital structures.

We dealt with intradural tumor growth in 8 cases (44% of pituitary adenomas, 25% of chordomas), and the average size of the dural opening was 1.75 cm. The most common complication was a cerebrospinal fluid (CSF) leak from the nose, which occurred in three patients. We inserted a lumbar drain in all of these patients for one week. Two of them needed revision surgery, and in one patient, the CSF leak stopped once the external lumbar drainage was inserted. We had to stop the procedure on one patient with craniopharyngioma due to severe bleeding from the venous plexuses in front of the clivus. We managed to achieve hemostasis, but we did not continue with the intradural stage of the operation. We continued with the procedure one week later when there was no excessive bleeding, and we successfully removed the tumor. One patient developed minor post-operative bleeding, which needed no revision surgery. There were no other major complications in our series.

We correlated complications with time and found that 2 out of 3 patients with CSF leakage had undergone surgery among the first 11 cases, and the 3rd patient with CSF leakage was the 13th patient to undergo surgery. We did not have any major complications in the last 6 cases. The mean surgical time in the first 10 cases was 342 minutes, while the mean surgical time in the last 9 cases was 297 minutes.

Discussion

On the basis of our results, we can say that the endoscopic transnasal approach to the clival region, performed at our institution, is safe and effective. None of the patients died in the perioperative or early post-operative phase. Complete removal of the pathological process was achieved in most of the patients. Apart from CSF leakage, there were no other major complications in our series.

In our series, the rate of post-operative CSF leakage was 16% (3 out of 19 patients), or 37.5% of patients with an intraoperative dural opening (3 out of 8 patients). We managed to stop the CSF leak in all cases. We inserted a lumbar drain in all of these patients for one week, and two of them needed revision surgery. One patient with a CSF leak developed bacterial meningitis, which was cured with appropriate antibiotic therapy. For skull base reconstruction and to reduce the risk of CSF leakage, we used a nasoseptal flap. We reconstructed the dura mater with two avascular layers and filled the clival defect with autologous fat tissue. Then, we covered the avascular reconstruction with the nasoseptal flap.

From a review of the literature, we found that the clival region can be divided into the upper, middle, and lower sections by the transverse lines located at the level of the dural entrance of the abducent and glossopharyngeal nerves. That separation is based on the concept of three neurovascular complexes in the posterior cranial fossa (3, 15). Approaches to the upper, middle, and lower sections of the clivus provide access to the anteromedial region of these three neurovascular complexes (1, 15, 16). An extended approach to the upper

section of the clivus allows access to the midbrain, the upper half of the pons, the superior cerebellar artery, and the oculomotor and trigeminal nerves in the upper neurovascular complex. Approaches to the middle section of the clivus provide access to the lower half of the pons, the anterior inferior cerebellar artery, and the abducent, facial and vestibulocochlear nerves in the middle neurovascular complex (1). The paraclival carotid artery represents the lateral limit of this approach. Extended approaches to the lower section of the clivus provide access to the medulla oblongata, the posterior inferior cerebellar artery, and the glossopharyngeal, vagus, accessory, and hypoglossal nerves in the lower neurovascular complex (1). The foramina lacera are the lateral limits of this approach at the lower section of the clivus.

The most common lesions involving the clival region are chordomas, chondrosarcomas, meningiomas, metastatic tumors, plasmacytomas, and lymphomas. Other paraclival lesions that can extend into the clivus are invasive pituitary adenomas, invasive nasopharyngeal carcinoma, and juvenile angiofibroma (17). Surgical resection is the primary treatment of most lesions. Radiation therapy may be considered, either as primary therapy for poor surgical candidates, or as adjuvant therapy for aggressive or recurrent disease (2).

Median tumors of the skull base are challenging targets for surgical treatment using standard transcranial approaches (18, 19). The endoscopic endonasal approach is a fast and effective method, characterized by high radicality, low risk of post-operative complications, and low mortality, and it is suitable for surgeons skilled in endoscopic surgical techniques (12, 18, 19).

Doglietto et al.'s quantitative anatomical study showed that endoscopic transnasal approaches to the clivus provide larger working volume and broader exposure of the clivus, compared to »classic« lateral approaches (20).

It is essential to understand the relationship between the extent of the involvement of the pathological process in the clivus or surrounding neurovascular complexes, and whether the process is located intradurally, extradurally, or both. The

transclival approach can also be used for different pathologies, not just for tumors in the clival region. It can be implemented for clipping centrally located posterior cranial fossa aneurysms, originating from the superior cerebellar artery, the anterior inferior cerebellar artery or the posterior inferior cerebellar artery (15).

The repair of clival skull base dural defects is often optimized with a multilayer closure, which is challenging on account of the inability to exert forceful pressure posteriorly, where critical structures are located (basilar artery, brain stem) (2). Multilayer closure can also help prevent pontine herniation through the clivus defect (21).

The extended endonasal transclival approach has several advantages compared to transcranial approaches. Some of the benefits are the patients' quick recovery, short hospital stays, and minimal post-operative discomfort (22-26). An endoscope allows a significantly wider and better-illuminated field of view (27). As a fully endoscopic procedure, there is no need to perform traction on various structures of the brain, and it provides a wider angle of exposure and a direct view of the midline structures. There is no need to displace the vertebral artery. It provides a well-lit surgical corridor and adequate visualization of even the most inaccessible regions (3-5, 28, 29). Since the endonasal surgical corridor is not associated with resection of the oropharynx and the soft palate, the risk of bacterial contamination and infection is low. The patients have a low risk of post-operative swallowing and speech disorders, and are capable of oral food intake, without the risk of dysphagia, immediately after surgery. There are also some drawbacks to the extended endoscopic transnasal approaches to the clivus, which can be challenging to perform in cases of atypical topography of the neurovascular structures located medially and anteriorly in relation to the tumor (1). Some other disadvantages are the limited working space, reduced maneuverability, and the need for special instrumentation (27). The use of the transnasal approach can also be associated with the risk of damaging the lateral parts of the cranial nerves (oculomotor, abducens, glossopharyngeal, and the vagus nerve)

(29). A relative contraindication for this approach is the significant lateral displacement of the tumor at the level of the foramen magnum, posterior to the occipital condyle, because there is a risk of craniocervical instability and injury to the caudal group of nerves (30). In cases of significant lateral extension of the lesion, it is preferable to choose a staged approach, combining a craniotomy with an endoscopic technique. A combined open and endoscopic approach allows the surgeon to deal with different components of the tumor most appropriately and directly (25). Absolute contraindications include tumors with invasion of the orbit, requiring exenteration, or involving the skin or anterior wall of the frontal sinus, and those that require microvascular reconstruction (31).

Extended endoscopic transnasal approaches can be considered as an independent and universal approach to pathological lesions of the skull base. The choice of approach should be based on the location of the tumor, the anatomical and clinical characteristics of the individual patient, as well as the level of the surgeon's proficiency in using endoscopic approaches (29, 32).

When we first started endoscopic skull base surgery at the University Medical Centre, Maribor, a surgical telementoring program was established with an experienced skull base team at the University of Pittsburgh Medical Center in Pennsylvania. The two-way video and audio streaming provided real-time communication between the surgical teams. The most frequent mentoring interventions concerned the identification of anatomy, the extent of exposure, the extent of resection, and the surgical technique. The assessment of the efficiency of this surgical telementoring program showed many benefits. (11). We correlated complications and surgical time with time. We showed that all of the complications happened among the first 13 out of 19 cases, while mean surgical time in the last 9 out of 19 cases were on average 45 minutes shorter. We still have limited data because of the low number of cases, but the results show the efficacy of the telementoring program, with fewer complications and shorter surgical time over time.

Endoscopic surgery in the clival region has potential complications (33). Intracranial complications can result from direct injury to the brain, cranial nerves, meninges, blood vessels, or venous sinuses. In the case of the brain and cranial nerves, the resulting deficits reflect the loss of function of the damaged structures. In the case of damage to blood vessels, resulting hematomas can create a mass effect, or loss of vascular supply can lead to stroke. Severe injuries of the internal carotid artery can be catastrophic and lethal. CSF leakage can cause symptoms directly and predispose to meningitis. Pneumocephalus can also cause mass effect symptoms (33).

The most frequent immediate complications are CSF leak, intraoperative bleeding, and injury to the brain-stem and/or intracranial nerves. Wide trepanation of the clivus and significant defects of the dura mater increase the risk of post-operative CSF leakage (1). The most frequent delayed complications are meningitis, delayed bleeding, and delayed CSF leak. There is also a possibility of transitory or permanent endocrinological complications that may result from manipulation, compression, or traction of the hypophysis (33). It is important to recognize and diagnose pituitary insufficiency early, and manage this condition promptly.

There are many techniques for skull base reconstruction, and to reduce the risk of CSF leakage. Some of them are the use of a balloon catheter, microsurgical duroplasty, and nasoseptal flap, which we use. With the use of these modern techniques, the risk of post-operative CSF leakage can be diminished to 0% - 9.5% (34-36).

Conclusion

The endoscopic transnasal approach to the clival region is safe, effective and provides better visualization of that region compared to other transcranial approaches. CSF leak is the most frequent complication. Successful endoscopic surgeries in this region are based on the development of new endoscopes, surgical instruments and operative materials, but more importantly, also on the sur-

geon's knowledge of anatomy, the mastering of endoscopic surgical techniques, and a multidisciplinary approach. In our series, we showed that the transnasal approach to the clival region can be effectively performed, even in small neurosurgical departments, for different kinds of clival pathologies. At first, this was made possible through a surgical telementoring program, established with an experienced skull base team.

What Is Already Known on this Topic:

The endoscopic endonasal approach has recently become one of the most frequently used methods in the surgical management of clival lesions, and is safe, effective and provides better visualization of that region compared to other transcranial approaches. With the help of modern reconstructive techniques, the rate of post-operative complications is lower, especially CSF leak. The most common lesions involving the clival region are: chordomas, chondrosarcomas, meningiomas, pituitary adenomas, metastatic tumors, and plasmacytomas.

What this Study Adds:

In our series, we showed that the transnasal approach to the clival region can be performed effectively, even in small neurosurgical departments, on a relatively small number of patients. In the beginning, the rate of complications was higher and the mean surgical time was longer. We showed that the learning curve can be steep with the help of a surgical telementoring program, established with an experienced skull base team.

Authors' Contributions: Conception and design: JR, BH, and BL; Acquisition, analysis, and interpretation of data: JR, BH, and BL; Drafting the article: JR, BH; Revising it critically for important intellectual content: JR, BL; Approved final version of the manuscript: JR, BH, and BL.

Conflict of Interest: The authors declare that they have no conflict of interest.

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