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Сравнительный анализ эндоскопической трансназальной и микрохирургической трансоральной одонтоидэктомии: обзор литературы и собственный опыт

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АННОТАЦИЯ

Обоснование. В случае передней компрессии стволовых структур инвагинированным зубовидным отростком показано выполнение одонтоидэктомии, которую в настоящее время возможно проводить как трансоральным микрохирургическим, так и трансназальным эндоскопическим доступом.

Цель. Провести сравнительный анализ эндоскопической трансназальной и микрохирургической трансоральной одонтоидэктомии, выполненных первым автором работы.

Материалы и методы. Проанализированы результаты лечения 29 пациентов с патологическими состояниями, включающими переднюю компрессию стволовых структур инвагинированным зубовидным отростком. Из 29 пациентов 5 (17%) человек оперированы трансназально эндоскопически, 24 (83%) — трансорально микрохирургически.

Результаты. Во всех случаях (100%) удалось достичь декомпрессии стволовых структур. Отсутствие необходимости в установке трахеостомы перед операцией и меньший объём травмы ротоглотки позволяют пациентам, подвергшимся трансназальному удалению зубовидного отростка, переносить послеоперационный период легче и быстрее.

Заключение. В настоящее время эндоскопический трансназальный доступ постепенно замещает трансоральный у ряда пациентов, которым показана передняя одонтоидэктомия. При этом анализ данных литературы отображает всё более глубокое развитие этой методики, однако однозначных показаний к применению трансорального или трансназального доступа в настоящее время не сформулировано.

Ключевые слова: удаление зубовидного отростка; трансоральная хирургия; эндоскопическая трансназальная одонтоидэктомия; эндоскопия.

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Comparative analysis of endoscopic transnasal and microsurgical transoral odontoidectomy: Literature review and own experience

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ABSTRACT

BACKGROUND: Odontoidectomy is indicated in the case of anterior compression of brainstem structures by an invaginated dentoid process, and it is currently possible to perform both transoral microsurgical and transnasal endoscopic access.

OBJECTIVE: To conduct a comparative analysis of endoscopic transnasal and microsurgical transoral odontoidectomy performed by the first author.

MATERIALS AND METHODS: The treatment results of 29 patients with pathological conditions, including anterior compression of stem structures with an invaginated dentoid process, were analyzed. Of 29 patients, 5 (17%) underwent surgery transnasally endoscopically, and 24 (83%) underwent surgery transorally microsurgically.

RESULTS: Decompression of brainstem structures was achieved in all cases. The absence of the need to install a tracheostomy before surgery and the smaller volume of oropharyngeal trauma allow patients to undergo transnasal removal of the dentoid process and endure the postoperative period easier and faster.

CONCLUSION: Currently, endoscopic transnasal access is gradually replacing transoral access in certain patients who are indicated for anterior odontoidectomy. Moreover, the literature analysis shows an ever deeper development of this technique; however, unambiguous indications of the use of transoral or transnasal access have not been formed at present.

Keywords: odontoid process removal; transoral surgery; endoscopic transnasal odontoidectomy; endoscopy.

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BACKGROUND

The craniovertebral junction (CVJ) is a complex transition zone between the skull and the cervical spine. It plays a crucial role in providing stability and facilitating movement of the head. The CVJ includes structures, such as the occipital bone, C_I and C_{II} vertebrae, ligaments, and neurovascular structures [1, 2]. The CVJ ensures 50% of the rotational movements of the neck (mainly at the level of the C_I–C_{II} vertebrae) and provides 30° flexion and extension of the cervical spine [3]. Pathological processes in the CVJ area are extremely difficult for both diagnostics and surgical treatment. This is due to the high concentration of critical structures, such as the brainstem, main arteries, cranial, and spinal nerves, in a relatively small volume of bone and soft tissues.

In the case of anterior compression of stem structures by an invaginated odontoid process, which can occur in various developmental anomalies or injuries [4–6], odontoidectomy is the recommended treatment. Currently, this procedure can be performed using either a transoral microsurgical approach or a transnasal endoscopic approach. The former treatment option is widely presented in the literature, providing detailed information about the technical characteristics of the surgery and its possible complications [7–9].

Endoscopic transnasal odontoidectomy was first described by A. Kassam [10]. In Russia, such a surgery was performed for the first time in 2010 when there were only about ten reported cases worldwide [11]. To date, the paraseptal transchoanal approach with trepanation of the posterior septum of the nose is the most commonly used technique, although some authors have described the use of submucosal subperiosteal approach [12–14]. The largest series, consisting of 34 surgeries, was presented by N.T. Zwagerman et al. in 2018 [15]. The number of publications describing the use of endoscopic transnasal approach for odontoidectomy has been steadily growing since 2005, which is confirmed by a meta-analysis conducted by N. Aldahak in 2017. This trend is attributed to the lower injury rate of this approach and fewer complications in the postoperative period [16]. Most of the publications presented in the global literature include 1–3 clinical cases, with a total patient count of not more than 320 (Table 1).

The study aimed to conduct a comparative analysis of endoscopic transnasal and microsurgical transoral odontoidectomy performed by the first author of the work.

MATERIALS AND METHODS

Study design

A retrospective cohort study was conducted.

Eligibility criteria

The inclusion criterion for patients in the study was odontoidectomy performed either with endoscopic transnasal (main group) or microsurgical transoral approach (control group). There were no exclusion criteria.

Terms and conditions

The study was conducted in two centers, namely, the N.N. Burdenko National Medical Research Center for Neurosurgery (Moscow) from 2010 to 2020, and the N.N. Priorov National Medical Research Center of Traumatology and Orthopedics (Moscow) from 2004 to 2018.

Table 1. World experience in endoscopic transnasal odontoidectomy

Author	Year	Number of patients	Stabilization	Complications
A. Simal-Julián [17]	2021	1	OSD	No
C. Zoia [18]	2021	1	OSD	No
J. Falco [19]	2021	1	OSD	No
R.S. Heller [20]	2021	7	OSD /C_I–C_{II}	No
H.N. Algattas [21]	2021	1	No	No
J.K. Liu [22]	2021	1	OSD	No
N.R. London Jr. [23]	2021	1	OSD	No
P. Veiceschi [24]	2021	1	No	No
Q. Husain [25]	2020	30	OSD	Dysphagia, asphyxia
E. Grose [26]	2020	17	OSD	Dysphagia, sinus infection, nasal hemorrhage, caudal cranial nerve dysfunction
V.M. Butenschoen [27]	2020	19	C_I–C_{II}	1 lethal outcome (osteomyelitis), dysphagia, asphyxia
M.-Y. Yeh [28]	2019	13	OSD	Cerebrospinal fluid leak
T. Ogiwara [29]	2019	1	OSD	No
A.F. Alalade [30]	2019	7	OSD	No
P. Pacca [31]	2019	1	C_I–C_{II}	No

Table 1. Table ending

Author	Year	Number of patients	Stabilization	Complications
M. Vitali [32]	2019	1	No	No
R.V. Abbritti [33]	2019	4	OSD	No
M. Ottenhausen [34]	2018	14	OSD	No
A. Grin [35]	2018	1	OSD	No
S. Aldea [36]	2018	12	OSD	No
N. Zwagerman [15]	2018	34	OSD	Velopharyngeal insufficiency, dysphagia, caudal cranial nerve insufficiency
D. Tang [37]	2018	1	OSD	No
I. Hussain [38]	2018	1	OSD	No
R. Herrera [39]	2018	1	OSD	No
Z. Rossini [40]	2018	5	OSD	No
M. Iacoangeli [41]	2018	7	Anterior C_I–C_{II}	No
H. Singh [42]	2018	4	OSD	No
M.A. Sexton [43]	2018	5	n/d	Asphyxia
S. Chibbaro [44]	2017	14	OSD	No
F. Zenga [45]	2016	12	OSD	No
V.R. Kshettry [13]	2016	1	OSD	No
F. Zenga [46]	2015	1	No	No
T.C. Burns [47]	2015	2	OSD	No
M. Zoli [48]	2015	2	OSD	No
G. Kahilogullari [49]	2015	1	OSD	Cerebrospinal fluid leak
E. La Corte [50]	2015	6	OSD	No
N.S. Chaudhry [51]	2015	1	No	No
T. Goldschlager [52]	2015	9	OSD	Nasal hemorrhage
J. Duntze [53]	2014	9	OSD	No
Y.S. Yen [54]	2014	13	OSD	Cerebrospinal fluid leak
O. Choudhri [55]	2014	5	OSD	Velopharyngeal insufficiency
D. Mazzatenta [56]	2014	5	OSD	No
T. Nagpal [57]	2013	1	n/d	No
F. Zenga [58]	2013	1	OSD	No
M. Iacoangeli [59]	2013	3	No	No
Y. Yu [60]	2013	3	OSD	Cerebrospinal fluid leak
R.B. Rawal [61]	2013	1	OSD	No
A.J. Patel [62]	2012	1	OSD	No
M. Gladi [63]	2012	4	OSD /No	No
A. Grammatica [64]	2011	1	OSD	No
J.F. Cornelius [65]	2011	1	OSD	No
F. Scholtes [66]	2011	1	No	No
I.H. El-Sayed [67]	2011	8	n/d	n/d
J. Gempt [68]	2011	3	OSD	No
A. Shkarubo [69]	2020	4	OSD	Cerebrospinal fluid leak
S. Magrini [70]	2008	1	Posterior fixation with bone graft	No
J.-C. Wu [71]	2008	3	OSD	No
J. Nayak [72]	2007	9	OSD	Velopharyngeal insufficiency
A. Kassam [10]	2005	1	OSD	No

Note. OSD, occipitospondylodesis; n/d, no data.

Target indicator assessing methods

In a common electronic database created in Microsoft Excel (Microsoft, USA), various indicators were recorded, including gender, age, nature of pathology, clinical presentation of the disease, radiological aspects, nature of the treatment and its characteristics, as well as clinical and radiological outcomes.

Ethical considerations

Due to the retrospective nature of the study, ethical review was not performed.

Statistical analysis

The data obtained was subjected to statistical analysis using the Statistica v. 10 software (StatSoft Inc., USA). Various indicators of surgical treatment of patient groups were compared, including the surgery duration, the degree of decompression of the stem structures, the volume of blood loss, the duration of hospitalization, and so forth.

The tasks of assessing the statistical significance of differences in the distributions of categorical and binary characteristics in groups were solved using the χ^2 test and Fisher's exact test. For numerical indicators, differences were assessed using the Mann–Whitney *U*-test, since the Shapiro–Wilk test and the Kolmogorov–Smirnov test showed that continuous indices were not normally distributed. The results of testing statistical hypotheses were recognized as statistically significant at a significance level of $p < 0.05$.

Descriptive statistics methods were also used to solve the problems. The data were presented in the format mean (M) ± standard deviation for normally distributed random variables and median (Me) and quartiles for random variables with non-normal distributions.

RESULTS

Participants (objects) of the study

We analyzed the treatment results of 29 patients. Group 1 consisted of five patients with anomalies in the CVJ development, namely, invagination of the odontoid process with or without basilar impression. In one case, the disease was accompanied by the formation of a syringomyelitic cyst at the level of the C_{III}–Th_{III} vertebrae, and in another case, it was accompanied by the Arnold–Chiari anomaly, where the cerebellar tonsils were lowered 19 mm below the Chamberlain line. The patients in this group were operated at the Neurosurgical Department 8 (basal tumors) of the N.N. Burdenko National Medical Research Center for Neurosurgery. The surgeries were performed using endoscopic endonasal approach.

For comparison, we analyzed group 2 (control) consisting of 24 patients with developmental anomalies, which included invagination of the odontoid process, or with acquired compression of the stem structures by the invaginated odontoid process (Fig. 1). Patients in this group were operated on from 2007 to 2020 at the N.N. Burdenko National Medical Research Center for Neurosurgery and N.N. Priorov National Medical Research Center of Traumatology and Orthopedics using the transoral microsurgical approach.

The indicators of demographic data, nosological entity, clinical symptoms and their dynamics in the postoperative period, aspects and scope of the surgery, development of

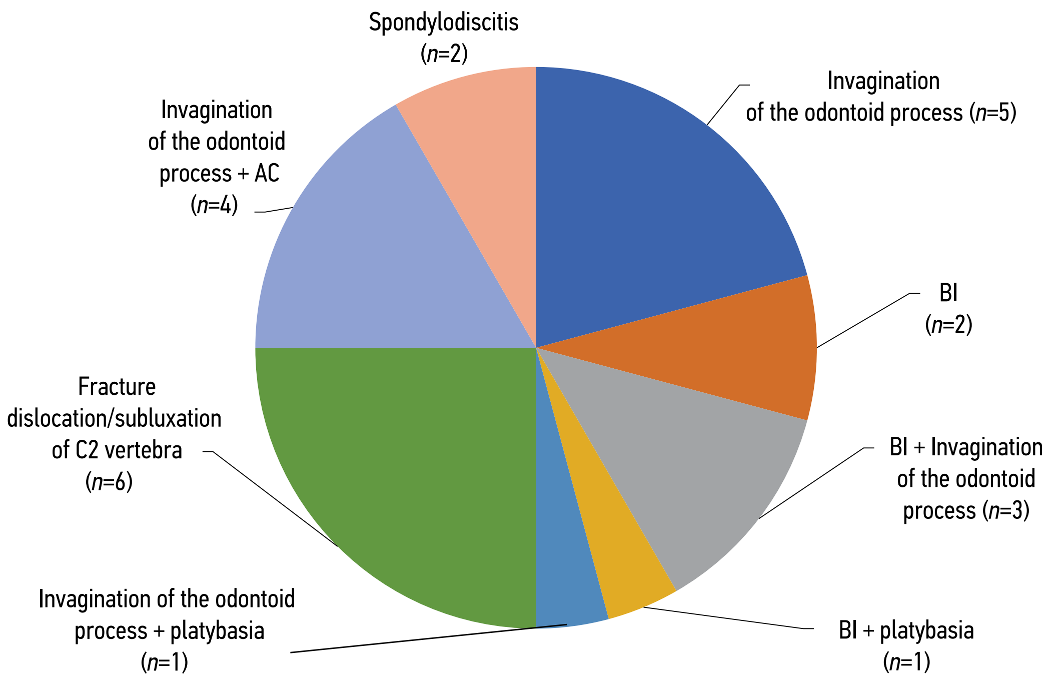

Fig. 1. Distribution of patients in the control group by nosology.
Note. БИ, basilar impression, АК, Arnold–Chiari anomaly.

Table 2. Clinical features of diseases

Symptom	Endoscopic transnasal odontoidectomy, *n* (%)	Transoral microsurgical odontoidectomy, *n* (%)
Tetraparesis	2 (40)	16 (66,7)
Hemiparesis	0	3 (12,5)
Headache	4 (80)	16 (66,7)
Cerebellar ataxy	1 (20)	9 (37,5)
Conduction sensory abnormalities	5 (100)	20 (83,3)
Bulbar disorders	1 (20)	4 (16,7)
Impaired control of pelvic organs	0	1 (4,2)

complications, and characteristics of patient management in the postoperative period were analyzed.

Among the patients of the group 1, there were four women and one man aged 22–60 years (median age, 51 years). The control group included 12 men and 12 women aged 11–60 years (median age, 33.5 years). The difference in the distribution of patients by gender was not statistically significant (p >0.05, Fisher's exact test).

The clinical presentation of diseases of the study participants is presented in Table 2.

In group 1, surgeries were performed using endoscopic techniques described in numerous studies [73–77]. In group 2, a classical transoral approach was employed, which is also widely presented in the literature. This approach includes such stages as the installation of a mouth expander, dissection of the soft palate, dissection of the posterior pharyngeal wall along the midline, skeletonization of the clivus, C_I and C_{II} vertebrae, trepanation of the anterior semi-ring of the C_I vertebra, trepanation and removal of the odontoid process, and layer-by-layer wound closure [78–81].

In two patients from group 1 and in seven patients from group 2, the surgery was two-staged. The first stage involved posterior stabilization (occipitospondylodesis (OSD)), followed by the main stage of the intervention after the patient was turned over. The removal of the odontoid process in both groups included the installation of a lumbar drain when necessary, placing the patient in a supine position for transoral approach and in a semi-sitting position for transnasal approach, and performing the appropriate approach. During the preparation for odontoidectomy, two patients were found to have initial CVJ instability: one case involved fracture dislocation of the odontoid process, and the other case involved odontoid process invagination with an unsuccessful attempt of posterior stabilization due to infectious complications.

Primary study results

Analysis of the results of endoscopic transnasal odontoidectomy

The results of surgical treatment were evaluated based on a retrospective analysis of the case histories of five patients whose odontoid process of the C_{II} vertebra was removed endoscopically transnasally (clinical case in Fig. 2).

Preoperative CVJ instability was not observed in any of the cases. Stabilization (OSD with the Vertex system) was performed in two patients, 1 and 3 months before the main stage of treatment. In two other patients, stabilization was performed simultaneously, as part of a two-stage surgical treatment. One of them (diagnosed with basilar impression, invagination of the odontoid process, syringomyelitic cyst at the level of C_{III} to Th_{III} vertebrae) underwent posterior decompression of the CVJ level during posterior stabilization. In one patient (diagnosed with intussusception of the odontoid process, Chiari anomaly type 1), CVJ was not stabilized. Despite the lack of assimilation of the C_I vertebra with the skull, and after 3 months of wearing a Philadelphia collar, the CVJ stabilization was registered.

In three out of five patients, a tracheostomy was placed before surgery. In one of the patients, a transoral approach was initially planned, but due to the stiffness of the mandibular joint, a transnasal approach was performed instead. In two cases, decannulation was performed within an average of 7 days (8 and 6 days), and, accordingly, oral nutrition was started on the days 8 and 2 after the surgery. Decannulation was not performed during hospitalization in one patient, due to the appearance of bulbar disorders. In the remaining two patients, mechanical ventilation of the lugs was performed orotracheally, and tracheostomy is not required during the postoperative period. Oral nutrition for these patients was started on the first day after surgery. The average time to start oral nutrition was 3 days after the surgery.

The average duration of odontoidectomy was 320±72.5 min. In four cases, trepanation of the lower clivus was performed to expand the approach zone. In these cases, the apex of the odontoid process was located behind the lower clivus. In two cases, trepanation of the upper sections of the C_{II} vertebra body was also performed to enhance the convenience of visualization during trepanation of the upper sections of the odontoid process, which enabled to hold the endoscope below the drill and control the underlying structures. In all cases, it was possible to perform a complete resection of the odontoid process and visualize a thinned, pulsating underlying dura mater (DM), which confirmed

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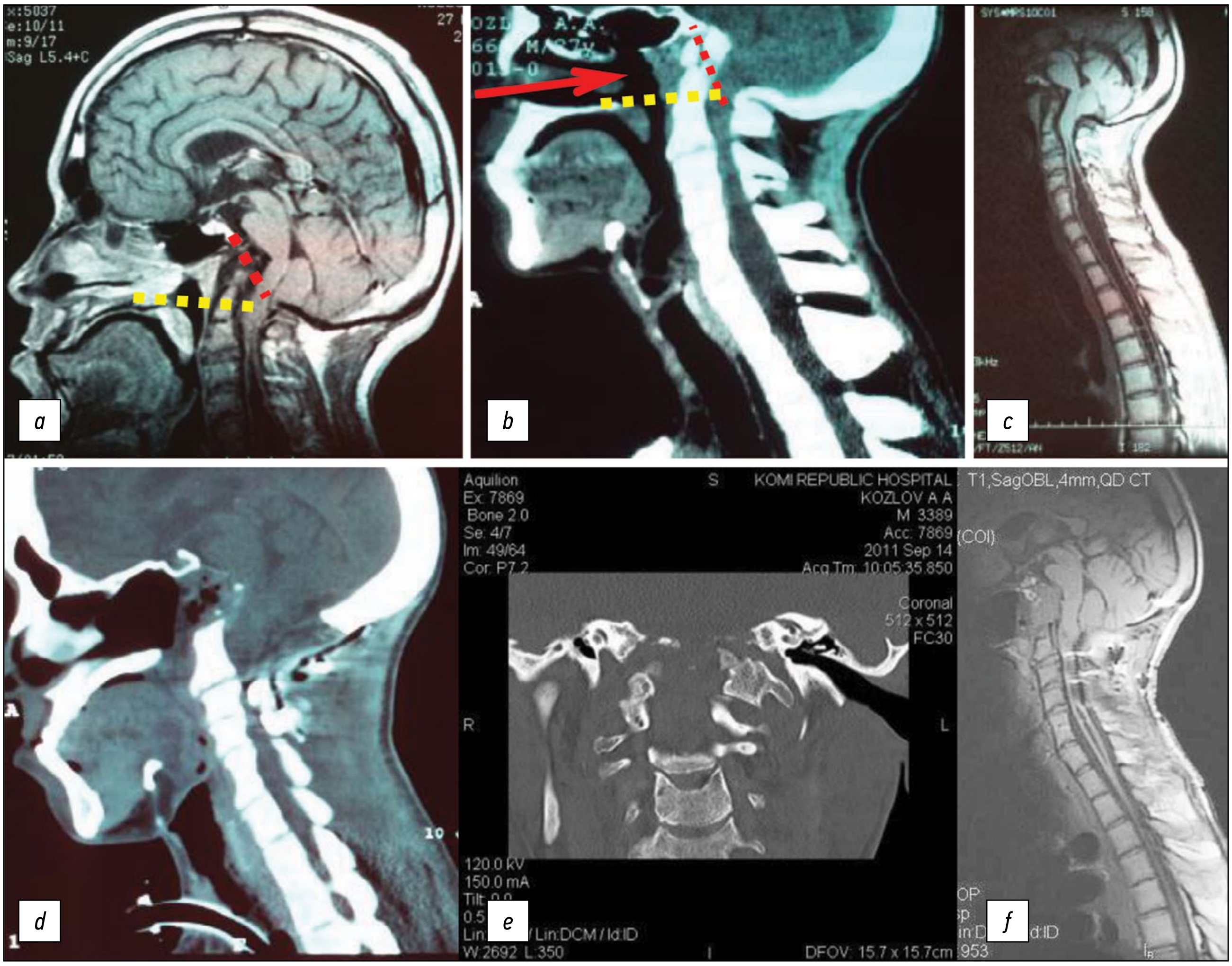

Fig. 2. Neuroimaging studies of patient K., 27 years old, before and after surgery.

Note. a — magnetic resonance imaging (MRI) before surgery. *b* — spiral computed tomography (SCT) before surgery. Invagination of the C_{II} vertebra odontoid compression of the medulla oblongata is determined. The red dotted line is the line of the plane of McRae's foramen magnum. The yellow dotted line indicates the Chamberlain line. The red arrow indicates the direction of access. The operating angle is 25 °. *c* — MRI before surgery, syringomyelitic cyst C_{III}–Th_{VII}. In the clinical picture — headache, hemiparesis 4 points. *d* — SCT 7 days after the operation. *e* — SCT 3 months after surgery. *f* — MRI of the head and neck in the sagittal projection in T_1 mode. Decompression of the medulla oblongata and spinal cord, almost complete regression of the giant syringomyelitic cyst.

the complete decompression of the stem structures at the intraoperative stage of treatment.

In two cases (the first two surgeries), at the last stages of the odontoid process removal, point damage to the DM was registered with the development of intraoperative cerebrospinal fluid leakage. Plastic surgery was performed with TachoComb and fibrin thrombin glue. However, in one of these cases, on the fourth day after the surgery, nasal cerebrospinal fluid leak and meningitis developed. As a result, a revision surgery was performed with layer-by-layer plastic surgery of the defect with autofascia and autofat. Damage to the main vessels was not observed in any of the cases. The average blood loss was 300 ml. The inclusion of the stabilization stage in the surgery increased blood loss by 500 ml.

In the range of complications, the development of pneumonia was also registered in one case after surgery.

Clinical symptom assessment was performed at the time of patient discharge. Positive changes were noted in two patients with initial tetraparesis, as they experienced a complete restoration of strength in the limbs. In one patient without initial motor impairment, deterioration was noted with the development of tetraparesis up to four points. In three out of four patients with cranialgia after surgery, regression of headache was recorded, while in one patient, no dynamics was registered. The only patient with ataxy showed regression of unsteady gait after surgery. All patients with sensory abnormalities had their regression in the early postoperative period (Fig. 3). A patient with Arnold–Chiari anomaly in the early postoperative period (day 7 after surgery) had a partial redislocation from the cerebellar tonsils of 19–15 mm and further redislocation up to 7 mm during 3 months of follow-up.

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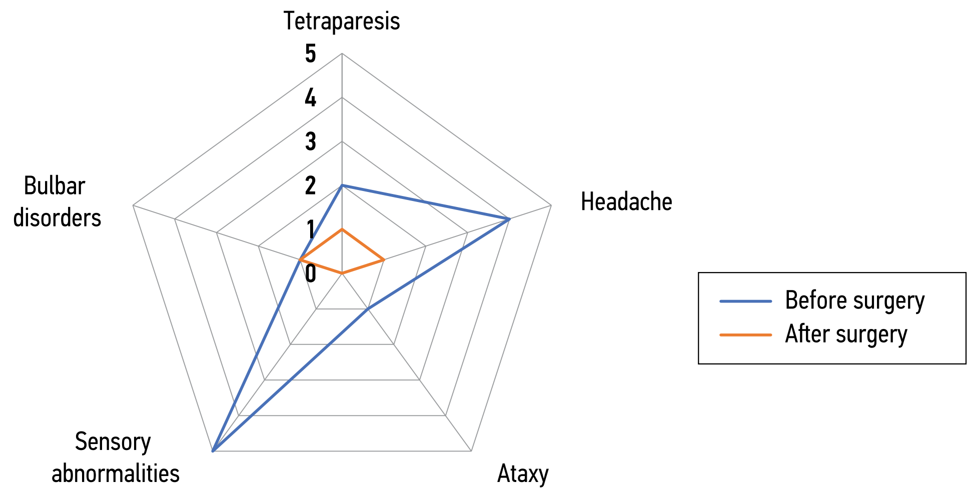

Fig. 3. Symptoms dynamics after surgery in the main group of patients (according to the number of patients).

The median duration of hospital stay after odontoidectomy was 12 days ± 18.9 (7–52 days). The longest hospital stay was 52 days in a patient with postoperative cerebrospinal fluid leakage and meningitis.

Analysis of the results of microsurgical transoral odontoidectomy

The results of surgical treatment were evaluated based on a retrospective analysis of the case histories of 24 patients whose odontoid process of the C_{II} vertebra was removed microsurgically transorally.

In 11 patients, the stabilizing surgery was performed single-staged. Among them, eight patients underwent OSD as stage 1 of the surgery, while in three patients, the stage 2 (anterior stabilization using an individual stabilizing system) was performed immediately after the removal of the odontoid process. In seven patients, stabilization was performed on average within a year prior to the main stage of surgical treatment. Additionally, in three cases, OSD was performed within 2 weeks after odontoidectomy. OSD was performed using the Vertex hook system in 11 cases, with the DM screw system in four cases, and with the Summit system in two cases. In one patient diagnosed with an invaginated odontoid process of the C_{II} vertebra, CVJ stabilization was not performed, despite the absence of assimilation of the C_I vertebra with the skull, and after 6 months of wearing a Philadelphia collar, the CVJ stabilization was recorded. In seven cases, OSD was accompanied by laminectomy at the C_I–C_{II} level.

A tracheostome was made in all patients prior to surgery. On average, decannulation was performed 11 days after surgery. The mean surgery time was 400 min, and the median duration of odontoidectomy was 380 min ([320; 450]). The OSD as stage 1 be prolonged the surgery by 525 min (median [480; 550]).

In five cases, trepanation of the lower parts of the clivus was performed to expand the approach zone. These cases involved situations where the apex of the odontoid process was behind the lower part of the clivus. Additionally, trepanation of the C_{II} vertebral body was performed in all cases. Complete resection of the odontoid process was achieved in 21 cases. In one case, dorsal cortical plastic surgery of the odontoid process was left; however, decompression of the stem structures was achieved. In another case, only half of the odontoid process was removed, which required repeated surgery, after which the odontoid process was completely removed. Furthermore, in one case, due to an orientation error in the surgical wound, instead of the odontoid process, trepanation of the anterior parts of the occipital bone condyle was performed (the error from the midline was 4 mm), and as a result, the patient underwent repeated surgery the next day, and the odontoid process was completely removed.

In two cases, at the last stages of the odontoid process removal, the DM damage and intraoperative cerebrospinal fluid leakage were noted. In case 1, plastic repair with TachoComb was performed. In case 2, plastic repair with TachoComb, autofat, and autofascia was performed. None of the patients developed meningitis or cerebrospinal fluid leakage in the postoperative period. In case 1, pneumonia developed after surgery.

In 15 cases, oral nutrition was started 3–4 days before decannulation. In four cases, the start of oral nutrition coincided with the day of decannulation. In the remaining three cases, due to bulbar disorders, oral nutrition was initiated 7–10 days after decannulation. In two cases, decannulation was not performed during hospitalization due to persistent bulbar disorders. The average time to start oral nutrition was 8.3 days.

In any case, damage to the main vessels was not registered. The average blood loss in patients who underwent posterior stabilization simultaneously with odontoidectomy was 1,040 ml. In patients who did not undergo stabilization or who underwent simultaneous anterior stabilization, the average blood loss was 416 ml.

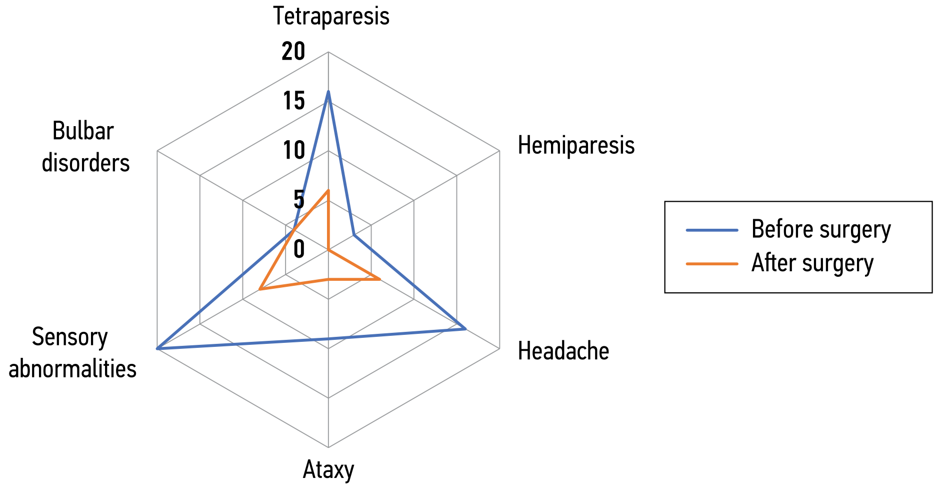

Fig. 4. Symptoms dynamics after surgery in the control group of patients (according to the number of patients).

Assessment of clinical symptoms was performed at the time of discharge of the patient from the hospital. In 10 out of 16 patients with initial tetraparesis, positive changes were noted in the form of increased strength in the limbs. None of the patients without initial motor impairment (n=5) had any of these in the postoperative period. All patients with initial hemiparesis (n=3) also showed improvement in the form of increased strength in the limbs. In 10 out of 16 patients with preoperative cranialgia, it regressed after surgery, while in six patients; it remained at the same level. Six out of nine patients had regression of ataxy.

In 12 out of 20 patients, regression of sensory abnormalities in the postoperative period was registered. In one out of four patients with bulbar disorders, improvement was registered. In two patients, the disorder degree persisted at the preoperative level, and in one case, it aggravated. In one patient, bulbar disorders occurred after surgery but regressed by the day 26 of the postoperative period. The changes in the clinical presentation over time are presented in Fig. 4.

The median duration of hospital stay after odontoidectomy was 18 days ([11.5; 28.5]). The longest hospital stay was 55 days in a female patient with a triple suture dehiscence on the posterior wall of the oropharynx in the postoperative period (clinical example in Fig. 5). Female patient N, aged 13, was admitted to the N.N. Burdenko National Medical Research Center for Neurosurgery. MRI and CT revealed platybasia, an invaginated odontoid process with compression of the stem structures (Fig. 5). In the neurological status, there was spastic tetraparesis (four points), bulbar disorders, and ataxy.

Adverse events

The incidence of surgical complications (cerebrospinal fluid leak, meningitis, and wound dehiscence) was not statistically significantly higher in the main group (20%) than in the control group (5%; p >0.05; Fisher's exact test; Table 3).

DISCUSSION

Discussion of the main study result

This study focused on the analysis of surgical treatment outcomes in patients with invaginated odontoid process, which compressed stem structures. The main indication for surgical treatment of pathological formations of the ventral CVJ, including in the presence of an invaginated odontoid process, is the compression of the brain stem and upper cervical segments of the spinal cord [82]. If the compression of the stem structures can be reduced by distraction, then posterior stabilization after distraction can only be performed, while stabilization provides a long-term effect of distraction [32, 83]. In cases of impossibility of distraction and progression of neurological symptoms, decompression of the stem structures and stabilization of the upper cervical segments of the spine are indicated [84]. Various approaches have been proposed for the treatment of such pathological processes, including transoral and transnasal endoscopic approaches [2, 10, 85–87].

With endoscopic transnasal approach, the surgical field is limited by the nasal and palatine bones, through which two lines are drawn, namely, the nasopalatine line proposed by A. Kassam (the line connecting the rhinion with the posterior edge of the hard palate), and the nasoclival line proposed by A. Shkarubo (the line connecting the rhinion and the lower clivus), resulting in a triangular shape of the surgical corridor [74, 88]. This corridor provides approach to the entire ventral CVJ in the median plane [10, 83]. In order to expand the approach zone in the caudal direction, trepanation of the posterior hard palate [2], its thinning to increase the excursion of the instruments [59], or a transseptal approach with trepanation of the posterior sections of the nasal septum [40] are used. On the sides, the surgical field is limited by the Eustachian tubes, medial pterygoid processes and paraclival sections of the internal carotid arteries. Orientation is possible using both neuronavigation and intraoperative CT/MRI [29].

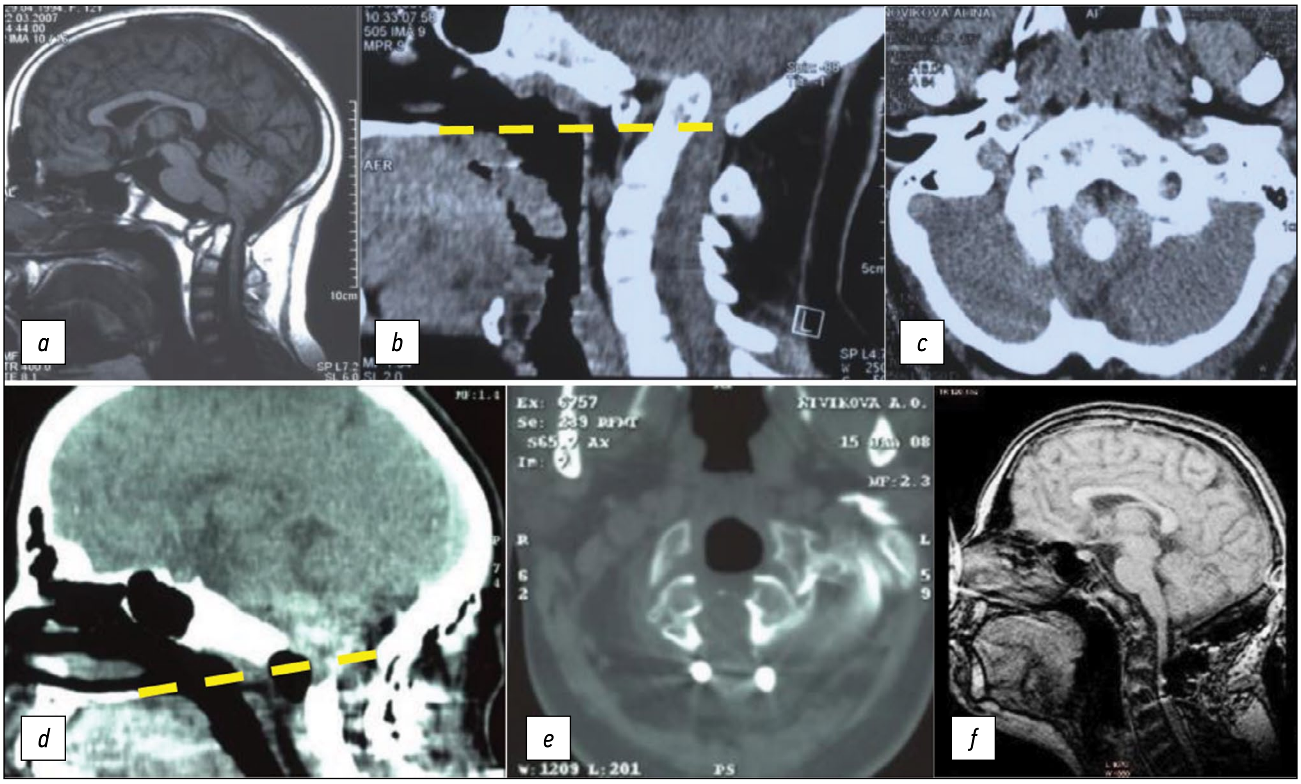

Fig. 5. Neuroimaging studies of patient N., 13 years old, before and after surgery.

Note. a — MRI in T_1 mode in the sagittal projection. *b* — SCT in the sagittal projection. *c* — SCT in axial projection. Platybasia, invagination of the odontoid is determined. The yellow dotted line is the Chamberlain line. The clinical presentation — a violation of swallowing, speech, weakness in the limbs, unsteadiness and instability when walking. *d* — SCT immediately after surgery (transoral odontoidectomy) in the axial projection. *e* — SCT immediately after the operation in the sagittal projection. *f* — MRI 2 years after surgery in the sagittal projection. There is decompression of the anterior spinal cord. The yellow dotted line is the Chamberlain line. On the 14th day after the operation, the sutures were removed from the posterior pharyngeal wall. The tracheostomy was removed on the 23rd day after the intervention. She was transferred to independent nutrition on the 23rd day after the operation (before that, nutrition was carried out through a nasogastric tube). In the neurological status: regression of tetraparesis, bulbar disorders. On the 43rd day after the intervention, the patient was discharged in a satisfactory condition.

Table 3. Surgical treatment complications

Complication	Main group, *n* (%)	Control group, *n* (%)
Cerebrospinal fluid leak	1 (20)	0 (0)
Meningitis	1 (20)	0 (0)
Wound dehiscence on the posterior pharynx	0 (0)	2 (8.3)
Pneumonia	1 (20)	1 (4.1)

According to the literature, the average rate of regression of neurological symptoms after transnasal odontoidectomy is 94% compared with 90% after transoral surgery [89]. It is important to note that there are no reported cases in the literature where neurological status worsened after endoscopic transnasal odontoidectomy, whereas the incidence of status worsening after transoral odontoidectomy is 0.9% [89]. In one case in this series, the emergence of tetraparesis motor disorders, more pronounced in the legs, was noted.

Since all patients in both groups achieved complete decompression of the stem structures, there was no significant difference in the dynamics of the clinical presentation between the groups. The most frequent symptoms, such as headache, motor and sensory abnormalities, regressed with a comparable frequency in both groups. This indicates the effectiveness of the technique applied and corresponds to the literature data, highlighting the efficiency of the actual anterior decompression [23, 24, 46, 90, and 91].

Due to the fact that transnasal approach to the odontoid process of the C_{II} vertebra is performed through a small incision in the nasopharynx, the influence of saliva and bacteria on the wound is reduced compared with transoral approach, which, accordingly, reduces the risk of infectious complications [23, 37, and 92]. Another advantage compared with transoral approach is the top-down approach trajectory, which allows better control of the stages of trepanation of bone structures and visualization of the ligamentous apparatus of the tooth from a more convenient position [16].

An important advantage of the transnasal approach is the absence of the need to install a tracheostomy, despite the literature suggesting its possible necessity in the postoperative period (due to transient velo-pharyngeal insufficiency or bulbar disorders), with a reported frequency of 2–3% [25, 72, 89]. This significantly differs from the rate among patients operated on transorally (26.3%) [93]. In the postoperative period in the group 1, there was no need to install a tracheostomy in any case, and patients who had it installed before the surgery underwent the decannulation procedure at the standard time, and oral nutrition for the patients of the main group was started at an earlier time, which was due, among other things, to a lower risk of wound infection and absence of risk of suture dehiscence on the soft palate and posterior pharyngeal wall, the incidence of which was 8.3% in group 2. According to the literature, the incidence of suture dehiscence averages 2% [89]. An equally important factor in the early start of oral nutrition is the lower (up to 6% according to the literature) probability of velo-pharyngeal insufficiency in patients after endoscopic transnasal odontoidectomy with the development of nasal voice and reflux of food into the nasal cavity, which is due to a lower concentration of pharyngeal plexus fibers in the incision area with endoscopic transnasal approach and absence of need to dissect the soft palate [9, 25, 89, 91]. In the study group, no such complications were registered after transnasal odontoidectomy in any case.

Complications

Transnasal endoscopic odontoidectomy is a new method, with several hundred surgeries described. Consequently, the question of possible intraoperative complications and postoperative complications becomes quite relevant. Like any surgery, the main possible intraoperative complication is bleeding. In none of the groups of our study, there was an injury to the great vessel, with a 2% incidence of such complications described in the literature [89]. However, the potential risk of such problems always exists, and it is always more difficult to achieve hemostasis in the conditions of endoscopic approach compared with the microsurgical technique used in transoral surgery. First of all, this is due to the lack of the possibility of full-fledged bimanual work. Nevertheless, the use of modern hemostatic agents and instruments designed for endoscopic endonasal surgery, including diamond burs and bipolar coagulation, as well as warm irrigation, allows for hemostasis [94]. It is also noteworthy that the level of blood loss observed in the study groups was comparable, which demonstrates that the transnasal endoscopic approach can be used on a par with microsurgical transoral approach. One of the possible complications that can be expected in the postoperative period is nasal hemorrhage, which occurs in 2% of cases [60, 62, 90, 95]. Similar to the approach to the sinus of the sphenoid bone, bleeding most often occurs from the branches of the sphenopalatine artery, and the only option for stopping it is wound revision and vessel coagulation. No such complications were noted in the series of cases analyzed.

Another possible complication is intraoperative cerebrospinal fluid leak, which in the case of odontoidectomy occurs due to the DM thinning in the site of the invaginated odontoid process and dense adhesion of the cortical plate to the DM, which is why it is most often noted at the very final stages of odontoidectomy. Despite the plastic surgery, there is always a risk of cerebrospinal fluid leakage in the postoperative period, which we recorded in one out of five (20%) patients of the study group, and which is comparable with literature data, where the frequency of such complications is approximately 2–20% (in an average of 6%), while the incidence of meningitis is on average 4% [28, 49, 54, 60, 89]. Such a high incidence is associated with the peculiarities of reconstruction of the osteodural defect in the CVJ area and clivus due to the size of the defects, the pronounced flow of cerebrospinal fluid, the absence of supporting structures, and the influence of gravity [92, 96]. In transoral surgery of the invaginated odontoid process, the incidence of cerebrospinal fluid leakage averages 1%, as well as that of meningitis, which is due to layer-by-layer suturing of the posterior wall of the nasopharynx and the possibility of more delicate exposure of the cortical plate of the odontoid process, which, accordingly, reduces the risk of injury to the DM [89]. The literature presents various techniques for repairing similar DM defects [1, 20, 23, 26, and 37]. The main methods of plastic surgery of a bone-dural defect in this area are a combination of methods of free transplantation (fat and fascia) and pedicled flaps. The “triple F” (fat, fascia, and flap) technique is mainly used [94, 97, 98]. Currently, as a rule, plastic repair is applied using a mucoperiosteal graft from the nasal septum and a graft formed from the posterior pharyngeal wall with or without autofat and autofascia. It is also possible to suture the posterior pharyngeal wall, which, of course, is more convenient to perform under conditions of microsurgical transoral approach.

According to the literature, extracranial complications after transoral odontoidectomy are most often cardial and pulmonological ones, which is mainly associated with tracheostomy and initial respiratory disorders [89, 99]. In the series described by us, similar complications were also registered in the form of pneumonia, which occurred in one case from each group of patients.

Stabilization of the craniovertebral junction

It is generally accepted that the removal of the anterior semi-ring of vertebra C_I and the odontoid process of vertebra C_{II} leads to instability of the atlanto-axial articulation, requiring internal or external fixation [72, 75, and 100]. Menezes and VanGilder noted in their work that 72% of 72 operated patients after odontoidectomy developed postoperative CVJ instability, which required posterior stabilization in a series of their patients (72 patients) [101]. The same data were also provided by Dickman on the experience of treating 28 patients, where in 70% of cases, stabilizing surgeries were required after resection of the odontoid process [102, 103].

In the absolute majority of cases, standard OSD is performed either before anterior decompression or after it [15, 26, 29, 37, and 104]. In some cases, C_I–C_{II} fixation is performed [20, 27, and 31]. At the same time, Chang et al. in a retrospective series of patients who underwent anterior odontoidectomy and various options for posterior stabilization (OSD with C_I–C_{II}–C_{III} fixation, OSD with C_{II}–C_{III} fixation, that of C_I–C_{II} only), using their algorithm (a triangle including the lower clivus point, posteroinferior point of the C_{II} vertebral body and the point of the odontoid process closest to the trunk), noted that the best decompression results are achieved in those who undergo occipitocervical stabilization with the inclusion of C_I–C_{II} segments [105].

An analysis of literature reveals the development of anterior stabilization methods that are not inferior in their effectiveness to the posterior one, which enables to perform the single-staged surgery, without turning over [103, 106–109]. A technique for anterior stabilization of the CVJ using a bone autograft has also been described [110]. To avoid the CVJ destabilization after odontoidectomy, some authors suggest removing the odontoid process without resection of the anterior semi-ring of the C_I vertebra by intraoperative repositioning of the head [41, 46, and 59]. Stabilization can also be omitted during fusion of the posterior semi-ring of the C_I vertebra and the occipital bone [32].

Study limitations

- Impossibility to trace catamnesis in all patients due to their unavailability
- No randomization of approach choice
- Large time scatter between the start and end of the enrollment of patients

CONCLUSION

Currently, the endoscopic transnasal approach is gradually replacing the transoral approach in a number of patients who require anterior odontoidectomy. At the same time, the analysis of literature data highlights the development of this technique, considering an increasing number of aspects of surgical treatment, including optimization of the size of the surgical field, attempts to perform C_I-preserving surgeries, and determination of a sufficient amount of trepanation of bone structures. However, unequivocal indications for the use of transoral or transnasal approach are not currently defined. Such indicators as nasopalatinal and nasoclival lines are used, but in most cases, the choice of approach depends on the equipment of the clinic and the skills of the surgeon. Nevertheless, the analysis of literature over the past 20 years shows a gradual shift in the emphasis of surgical treatment of patients with basilar impression toward minimally invasive techniques that can reduce the incidence of postoperative complications, shorten the patient’s stay in the hospital and reduce the frequency of stabilizing surgeries, which can significantly improve the quality of life of patients due to the absence of impaired mobility of the cervical spine. In our opinion, a promising field could be the development and implementation of a method for simultaneous anterior stabilization during endoscopic transnasal odontoidectomy using autografts or allomaterials.

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