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SURGICAL TREATMENT OF PATIENTS WITH SYMPTOMATIC KIMMERLE'S ANOMALY USING VIDEO ENDOSCOPY

A.G. Vinokurov[1], A.A. Kalinkin[1], A.A. Bocharov[1], A.V. Yarikov[2, 3], G.M. Yusubalieva[1, 4], O.N. Kalinkina[5]

[1] Federal Scientific and Clinical Center for Specialized Medical Assistance and Medical Technologies of the Federal Medical Biological Agency, Moscow, Russian Federation

[2] Privolzhsky District Medical Centre, Nizhny Novgorod, Russian Federation

[3] City Clinical Hospital 39, Nizhny Novgorod, Russian Federation

[4] Engelhardt Institute of Molecular Biology of the Russian Academy of Sciences, Moscow, Russian Federation

[5] Moscow State University of Medicine and Dentistry named after A.I. Evdokimov, Moscow, Russian Federation

ABSTRACT

Background: *Clinical manifestations of Kimmerle's anomaly are detected in 5.5 to 20% of patients. The main reason for the development of symptoms is prolonged compression of the V3 (atlantic) segment of the vertebral artery in the bone ring as a result of the atlantooccipital membrane's exostosis. To date, the final tactics for treating patients with Kimmerle's anomaly has not been determined. The effectiveness of conservative methods of therapy does not exceed 40%.* ***The aim*** *Of this study was to evaluate the results of a minimally invasive surgical treatment of patients with symptomatic Kimmerle's anomaly using video endoscopic assistance.* ***Methods:*** *In the period from 2020 to 2022, 15 patients were operated on. The indication for the surgical treatment was the lack of the conservative therapy's effect for 1 year from the onset of the disease, aggravation of the disease symptoms, a decrease in the blood flow through the vertebral artery at the Kimmerle's anomaly side when turning the head. The vertebral artery decompression was performed using video endoscopy through a posterior median approach in two (13%) patients and through a paravertebral intermuscular approach (4 cm incision in the occipitocervical region in the projection of the Kimmerle's anomaly) in thirteen (87%) patients.* ***Results:*** *The outcome of the disease was assessed at the time of discharge from the hospital, as well as in 6 and in 12 months after the operation. Following the surgical treatment, all the patients showed the complete regression of symptoms and restoration of the blood flow velocities in the vertebral artery. There were no complications after the operation. The use of video endoscopy made it possible to reduce the size of the surgical wound from 12 cm to 4 cm, which contributed to a decrease in the intensity of pain in the postoperative period, early activation and a decrease in the duration of the inpatient treatment.* ***Conclusion:*** *With the proper selection of patients with Kimmerle's anomaly, decompression of the V3 segment of the VA using video endoscopy is a safe and effective method of treatment.*

Keywords: *Kimmerle anomaly; vertebral artery; microsurgical decompression; videoendoscopy.*

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BACKGROUND

Kimmerle's anomaly (KA) is characterized by compression of the V3 (atlanto-occipital) segment of the vertebral artery due to exostosis of the atlanto-occipital membrane. This anomaly was first described by Hayek in 1923 and later named after Kimmerle identified its influence on the development of ischemic stroke in the vertebral–basilar basin [1–4].

The prevalence of KA in the population ranges from 9% to 37%, and clinical manifestations are found in 5.5%–20% of patients [5, 6]. The occurrence of symptoms depends on several factors, such as loss of vascular wall elasticity, atherosclerosis, vasculitis, periarterial scarring, small bony canal, large width of the vertebral artery, and osteochondrosis of the cervical spine [7, 8]. Because of long-term compression of the vertebral artery in the bone canal, its wall structure undergoes secondary changes, leading to early development of sclerotic processes. These processes are accompanied by hemodynamic disturbances in the vertebral–basilar basin, resulting in a decrease in blood flow volume by more than 30% and a decrease

ХИРУРГИЧЕСКОЕ ЛЕЧЕНИЕ ПАЦИЕНТОВ С СИМПТОМНОЙ АНОМАЛИЕЙ КИММЕРЛЕ С ПРИМЕНЕНИЕМ ВИДЕОЭНДОСКОПИИ

А.Г. Винокуров[1], А.А. Калинкин[1], А.А. Бочаров[1], А.В. Яриков[2, 3], Г.М. Юсубалиева[1, 4], О.Н. Калинкина[5]

[1] Федеральный научно-клинический центр специализированных видов медицинской помощи и медицинских технологий, Москва, Российская Федерация

[2] Приволжский окружной медицинский центр, Нижний Новгород, Российская Федерация

[3] Городская клиническая больница № 39 Канавинского района г. Нижнего Новгорода, Нижний Новгород, Российская Федерация

[4] Институт молекулярной биологии имени В.А. Энгельгардта, Москва, Российская Федерация

[5] Московский государственный медико-стоматологический университет имени А.И. Евдокимова, Москва, Российская Федерация

АННОТАЦИЯ

Обоснование. *Клинические проявления аномалии Киммерле выявляют у 5,5–20% пациентов с этим заболеванием. Основной причиной развития симптомов является длительная компрессия V3 (атлантового) сегмента позвоночной артерии в костном кольце, образованном вследствие экзостоза атлантозатылочной мембраны. До настоящего времени не определена окончательная тактика лечения пациентов с аномалией Киммерле. Эффективность консервативных методов терапии не превышает 40%.* ***Цель исследования*** *— оценить результат миниинвазивного хирургического лечения пациентов с симптомной аномалией Киммерле с применением видеоэндоскопической ассистенции.* ***Методы.*** *В период с 2020 по 2022 год прооперировано 15 пациентов. Показанием к оперативному лечению явились отсутствие эффекта от консервативной терапии на протяжении года после дебюта заболевания, нарастание симптомов заболевания, снижение кровотока по позвоночной артерии со стороны аномалии Киммерле при поворотах головы. У 2 (13%) пациентов декомпрессию позвоночной артерии выполнили из заднего срединного доступа, у 13 (87%) — из паравертебрального межмышечного (разрез 4 см в шейно-затылочной области в проекции аномалии Киммерле) с применением видеоэндоскопии.* ***Результаты.*** *Оценку исхода заболевания проводили при выписке из стационара, а также через 6 и 12 месяцев после операции. После хирургического лечения у всех пациентов отмечены полный регресс симптоматики, восстановление скорости кровотока по позвоночной артерии. Осложнений после операции не было. Применение видеоэндоскопии позволило уменьшить размер операционной раны с 12 до 4 см, что способствовало снижению интенсивности болевого синдрома в послеоперационном периоде, ранней активизации и уменьшению длительности стационарного лечения.* ***Заключение.*** *При правильном отборе пациентов с аномалией Киммерле декомпрессия сегмента V3 позвоночной артерии с применением видеоэндоскопии является безопасным и эффективным методом лечения.*

Ключевые слова: *аномалия Киммерле; позвоночная артерия; микрохирургическая декомпрессия; видеоэндоскопия.*

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in blood flow of the main artery by 40% [1, 9]. In 13.1% of patients with KA, magnetic resonance imaging (MRI) of the brain reveals ischemic lesions [1, 10].

Patients diagnosed with KA experience vertebral artery compression on the side of the anomaly, resulting in a decrease of blood flow through the ipsilateral vertebral artery up to 25% [1, 11].

The main clinical manifestations of the disease include headache, neck and upper extremity pain, vertebral–basilar insufficiency, Barre–Lieou syndrome

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or Bow Hunter's syndrome, hearing loss, and visual and radicular disorders [1, 12, 13].

Disease symptoms var**y** depending on its duration and the degree of compression in the bone canal of additional structures, such as veins, sympathetic plexus, and C1 root [1, 2]. Patients are often misdiagnosed with other conditions, such as cervical spine osteochondrosis, occipital neuralgia, migraine, tension headache, or vegetovascular dystonia [14, 15].

There are two anatomical variants of KA: posterior and lateral. In the former, a bone bridge forms between the articular process of the C1 vertebra and its posterior arch. In the latter, a bridge forms between the articular and transverse processes of the C1 vertebra [1, 16, 17] (Fig. 1).

Conservative and surgical treatments are used for symptomatic AK. Gulyaev et al. [2] have revealed a direct correlation between the duration of the disease and severity of clinical symptoms and noted that 60% of patients experienced a relapse of the disease after drug and physical therapy. Surgery results in symptom regression in 90% of cases, and an improved blood flow through the vertebral artery is observed in 95% [1, 18, 19].

Although symptomatic KA occurs frequently, studies that report the results of surgical treatment for these patients are few [1, 20, 21]. This lack of information makes it difficult to develop a unified opinion on the necessity of surgical treatment. Additionally, there is no description of vertebral artery decompression techniques using video endoscopy. Therefore, this study is highly relevant.

This study aimed to evaluate the outcome of minimally invasive surgical treatment of patients with symptomatic KA using video endoscopic assistance.

METHODS

Study design

A retrospective clinical study was conducted.

Eligibility criteria

The *inclusion criteria* were age >18 years, a diagnosis of KA confirmed by computed tomography (CT) angiography (complete bony ring at the level of the C1 vertebra), ineffective conservative therapy within 12 months from disease onset, progression of clinical symptoms, and positive functional tests (when turning the head, reduction of blood flow velocity through the V3 segment of the vertebral artery by >30%).

The *exclusion criteria* included refusal to participate, age 18 years, incomplete bone ring at the level of the C1 vertebrae, traumatic brain injury, cervical spine trauma, brain pathology, brachycephalic arteries, and cervical spine pathology.

Settings

The study was conducted in 2020–2022 at the Neurosurgical Department of the Federal Medical and Biological Agency of Russia.

Description of the medical intervention

Fifteen patients with symptomatic KA underwent surgical treatment. Preoperative angioregime CT images of the cervical spine revealed a posterior bone bridge compressing the vertebral arteries, periarterial nerve plexus, and veins.

Surgical treatment was indicated because of symptomatic KA, lack of response to conservative therapy for 12 months from disease onset, worsening symptoms, and positive functional tests (e.g., decreased

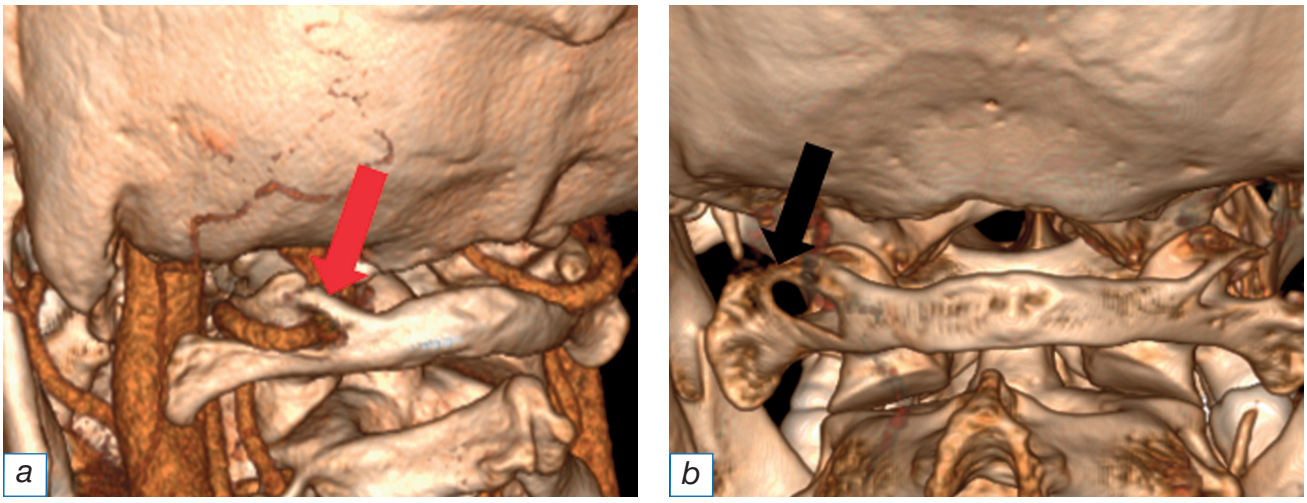

Fig. 1. Computed tomography of patients with 3D reconstruction in patients with Kimmerle's anomaly (*a, b*). The red arrow indicates the rear bridge, and the black arrow indicates the side bridge.

blood flow through the vertebral artery on the KA side when turning the head).

Surgery was performed with the patient in the supine position and the head fixed in a Mayfield brace. The cervical spine was maximally flexed to improve craniovertebral junction visualization.

Two techniques for vertebral artery decompression were evaluated: standard and minimally invasive techniques with video endoscopic assistance.

The present study included 15 patients treated at the Neurosurgical Department of the Federal Medical and Biological Agency of Russia. Two patients were treated using the standard method, which involved decompression from the posterior median access. The remaining 13 patients underwent minimally invasive interventions via paravertebral intermuscular access. This method involved a 4-cm incision in the cervico-occipital region in the projection of KA and video endoscopy.

Surgery: Two patients underwent surgery using different types of incisions. One patient had a T-shaped (crossbow) incision, and the other had an L-shaped incision along the midline, starting from the spinous process of the C2 vertebra and continuing 2 cm above the external occipital protrusion with an average 5 cm bend toward the KA (Fig. 2). The total length of the wound was 12 cm. After dissecting the soft tissues and skeletonizing the occipital bone, spinous processes of the C1 and C2 vertebrae, and the atlanto-occipital joint, the bone bridge and the site where the vertebral artery exits from the bone canal of the transverse process of the C1 vertebra were exposed. We then performed decompression of the vertebral artery using a microscope, microsurgical instruments, and a diamond-tipped burr. Once the main stage was completed, the postoperative wound was sutured layer by layer.

Thirteen patients (87%) underwent paravertebral intermuscular access with a 4-cm incision in the cervico-occipital region in the projection of the KA, assisted by video endoscopy. The use of video endoscopy allowed for a reduction in the size of the incision to 4 cm, visualization in the compression zone, and full decompression of the vertebral artery.

Surgical progress: The patients were positioned on their abdomen, with the head fixed in a Mayfield brace. The incision was projected 2.5 cm from the midline and had a length of 4 cm. The skin and subcutaneous fat were dissected using a scalpel, and the aponeurosis was dissected using monopolar coagulation. To expose the bony bridge of the C1 vertebra, the bundles of *m. trapezius, m. semispinalis capitis*, and *m. rectus capitis* posterior major were dissected using a sterile probe tampon. This study examined the compression zone of the V3 segment of the vertebral artery after retractor placement. An Aesculap endoscope (Germany) with a 2.7-mm diameter and 0° and 30° viewing angles was used. The vertebral artery was then decompressed using a microscope (ZEISS OPMI PENTERO 900), a diamond-tipped drill, and microsurgical instruments. In areas that were not visible under the microscope, bony structures were resected using endoscopy. After the bone ring was removed, significant scarring was observed around the vertebral artery, indicating long-term trauma in the KA region. Following the main stage, the postoperative wound was sutured layer by layer (Fig. 3).

Visual assessment of vertebral artery decompression was performed during surgery and in the postoperative period using angioregime CT and duplex examination of blood flow along the V3 segment of the vertebral artery.

Fig. 2. Images of a patient with symptomatic Kimmerle anomaly: *a* — preoperative 3D computerized reformation in a patient with the posterior Kimmerle anomaly type (indicated by arrow); *b* — intraoperative images of the alleged skin incision; *c* — postoperative 3D computerized reformation with a resected bone bridge at the level of the C1 vertebra.

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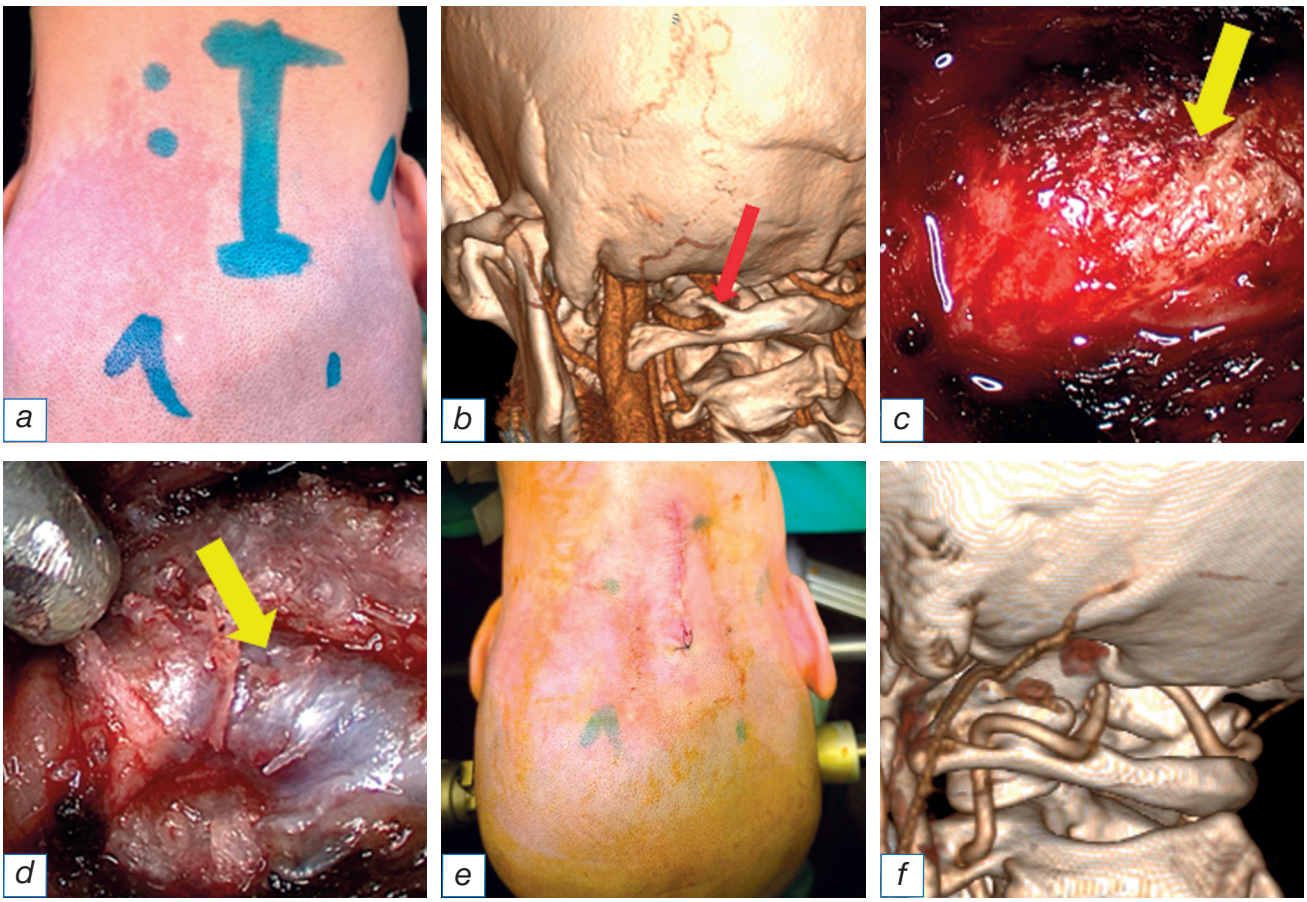

Fig. 3. Images of a patient with symptomatic Kimmerle's anomaly: *a* — incision projection; *b* — preoperative 3D computerized reformation in a patient with the posterior Kimmerle's anomaly type; *c* — endoscopic intraoperative image of the bone bridge in a patient with Kimmerle's anomaly; *d* — endoscopic intraoperative image of the vertebral artery after decompression; *e* — a picture of a postoperative wound; *f* — postoperative 3D computerized reformation with a resected bone bridge at the level of the C1 vertebra.

Methods for recording outcomes

The severity of the condition was assessed using the classification proposed by Gulyaev et al. [2] and the Rankin scale and Rivermead Mobility Index. Pain syndrome was evaluated using a 10-point visual analog scale, where 0 indicates no pain and 10 intolerable pain. These scales are widely accepted and accurately reflect the clinical outcomes of surgical treatment. No complications were reported after surgical treatment.

Ethical review

The study received approval from the local ethical committee of the Federal Medical and Biological Agency of Russia (protocol no. 2022/04/02; April 02, 2020). Patients or their legal representatives provided voluntary informed consent for the study and publication of the results.

Statistical analysis

Statistical processing was performed using nonparametric methods in the Statistica 12.0 program (StatSoft, Russia). Data are presented as the median and percentiles (25% and 75%).

RESULTS

Objects (participants) of the study

Fifteen patients (5 men and 10 women) underwent surgery for symptomatic KA. The median age of the patients was 31 years (range: 26–35). The first clinical manifestations appeared at a median age of 8 years (range: 6–12) before surgical treatment. Before surgery, all patients were examined by a neurologist and an otolaryngologist. The median duration of conservative therapy, including medication, physical therapy, and acupuncture, was 6 years (range: 4–11).

Symptomatic KA was diagnosed by a neurologist and an ear, nose, and throat (ENT) physician after a differential diagnosis.

The severity of the condition was assessed using the classification by Gulyaev et al. and the Rankin scale [2].

Gulyaev et al. [2] have identified three grades of severity of the disease course in patients with KA: mild,

moderate, and severe (Table 1). Grade I is characterized by pain syndrome with hemoliquorodynamic disorders. Grade II presents with mild symptoms along with vegetative disorders. Grade III (most severe degree) exhibits a frequency of the main syndromes ranging from monthly to weekly.

Of the 15 patients evaluated, 4 (27%) were classified as grade III, with 3 of them having KA on both sides and 1 having bilateral posterior type combined with lateral type. There were 8 (53%) patients with grade II and 3 (20%) with grade I. Before surgery, 1 (7%) patient had grade III impairment according to the Rankin scale and 11 (73%) patients had grade II and 3 (20%) had grade I. The Rivermead Mobility Index was used to evaluate all patients. Two of 15 participants (13%) scored 10, another 2 (13%) scored 11, 6 (40%) scored 12, and the remaining 5 (34%) scored 13.

Upon admission to the hospital, all patients exhibited general cerebral symptoms and vertebral–basilar insufficiency, including dizziness, impaired coordination, asthenic manifestations, tinnitus, and headache. Additionally, 2 (33%) patients experienced drop attacks, which are sudden falls with preserved consciousness. These symptoms were triggered by physical or prolonged static loads or by turning the head to the side. In 2 (33%) patients, symptoms occurred even at rest.

Main results of the study

The disease outcome was evaluated at hospital discharge and at 6 and 12 months postoperatively.

Following surgical treatment, all patients exhibited symptom regression, restoration of blood flow velocity along the vertebral artery, and no changes in these parameters in functional tests, confirming the adequacy of decompression (Table 2).

Patients with grade I and II severity experienced complete regression of vertebral–basilar insufficiency symptoms, including dizziness and noise in the head, both at rest and during physical activity and head rotation.

At hospital discharge, 20% of patients with grade I severity according to the scale of Gulyaev et al. [2] reported an impairment of vital activity corresponding to grade 0 on the Rankin scale (compared to grade I before surgery) and had a mobility index of 15 points on the Rivermead scale (compared to 13 points before surgery).

In 8 of 15 patients (53%) with grade II severity after surgical treatment, the impairment of vital signs on the Rankin scale corresponded to grade 0 (compared to grade II before surgery). The Rivermead Mobility Index was 14 and 15 points (compared to 12 and 13 points before surgery).

After surgical treatment, 4 of 15 patients (27%) with grade III severity showed improvement in vital activity, corresponding to grade 0 or I on the Rankin scale. Before surgery, these patients had grade II or III impairment. Additionally, their Rivermead Mobility Index improved from 10–11 points to 14 points.

The regression of disease symptoms in the postoperative period was longer in patients with more severe KA. Specifically, 2 of 4 patients with grade III severity of the disease according to the scale of Gulyaev et al. [2] experienced asthenic manifestations, headache, and dizziness for 8 months after surgery.

Table 1

Distribution of patients with Kimmerle's anomaly according to different scales upon their admission to hospital

Scale	Severity of the condition according to Gulyaev's scale (*n*=15)		
	I (*n*=3)	II (*n*=8)	III (*n*=4)
Rankin, grade	I	II	II–III
Rivermead, scores	13	12–13	10–11

Table 2

Evaluation of the outcome of surgical treatment in patients with Kimmerle's anomaly according to different scales

Scale	Severity of the condition according to Gulyaev's scale (*n*=15)		
	I (*n*=3)	II (*n*=8)	III (*n*=4)
Rankin, grade	0	0	0–I
Rivermead, scores	15	14–15	14

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However, all patients had a good or excellent outcome 6–12 months postoperatively. Regardless of the surgical approach, the Doppler study revealed restoration of blood flow velocity in the vertebral artery, with no changes observed during functional tests.

In our study, patients who underwent T- and L-shaped soft tissue incisions experienced more pain in the postoperative period than those who underwent minimally invasive access.

However, the access method did not affect the adequacy of decompression of the V3 segment of the vertebral artery.

DISCUSSION

In our study, the time from the onset of initial symptoms (headache, dizziness, shaky gait, and drop attacks) to diagnosis and referral to a neurosurgeon ranged from 4 to 15 years. Patients were observed by a neurologist, ENT physician, and therapist for an extended period (average: 7.2±3.2 years).

Patients diagnosed with KA experience pain, autonomic dysfunction, and vertebral–basilar insufficiency syndrome [1, 2, 4]. Pain syndrome is characterized by headaches that radiate to the eye, ear, upper arm, shoulder, and pharynx. Visual field impairment or metamorphopsia may occur. In vertebral–basilar insufficiency, noise illusions in the form of buzzing, rustling, squeaking, or whistling may be present. Possible sensory disturbances, cerebellar and bulbar symptoms, monoparesis, paraparesis, tetraparesis, sudden falls without loss of consciousness (drop attacks), and sudden falls with loss of consciousness (Unterharnscheidt's syncopal syndrome) may occur. Complaints may accumulate with head movement in the cervical spine. Vegetative syndrome (panic attack syndrome) is characterized by a "hot flush" to the head, accompanied by fear, anxiety, a feeling of suffocation, and other symptoms.

Upon admission to the hospital, patients in our study exhibited general cerebral symptoms and symptoms of vertebrobasilar insufficiency, including dizziness, impaired coordination, asthenic manifestations, tinnitus, and headache. Additionally, 40% of patients experienced drop attacks. Symptoms of the disease were observed during physical activity and prolonged static loads and when turning the head to the side. In 40% of patients, symptoms occurred at rest.

KA is a significant risk factor for the early development of stroke, specifically acute cerebral circulation disorder [1–4]. Clinical cases have shown a correlation between KA and acute hearing loss and spinal stroke [1, 21].

In our study, two patients with grade III severity of the condition experienced persistent symptoms such as headache and dizziness in the postoperative period. However, the severity of these symptoms decreased by 50% compared to that in the preoperative period. Complete regression of symptoms occurred after 8 months, and the existing drop attacks did not recur the entire observation period. Partial persistence of disease symptoms in the postoperative period may be related to the duration of the disease and severity of the main symptoms. This is supported by intraoperative findings, such as pronounced scar tissue around the vertebral artery in the KA region.

Following surgical treatment, patients with grade I and II vertebral–basilar insufficiency experienced complete regression of symptoms, including headache, dizziness, unsteadiness when walking, and head noise, at rest and during physical activity and head rotation.

All patients showed good to excellent outcomes of the disease 6–12 months postoperatively.

During the diagnostic stage, spondylography of the cervical spine is recommended as the first step to rule out KA [20]. However, this method has the disadvantage of difficulty in determining the KA side and the degree of bone ring closure due to the layering of additional bony structures. CT or MRI can be used in angioregime to determine the affected side, course of the vertebral artery, and severity of the bony ring and to rule out any other underlying conditions (e.g., stenoses or tortuosities of the neck and brain arteries) that may cause similar symptoms [1, 2, 6]. The linear velocity of blood flow before and during functional tests can be determined by duplex examination of the vertebral artery at the level of the V3 segment [8, 21]. Ischemia can be identified by MRI or CT of the brain. Vestibulometry is used for differential diagnosis. Caloric tests are performed at the prehospital stage.

The differential diagnosis of KA includes migraine, tension headache, autonomic dysfunction syndrome, Meniere's disease, vestibular neuronitis, labyrinthitis, bridging cerebellar angle syndrome, IV ventricular tumor, degenerative–dystrophic diseases of the cervical spine, Arnold–Chiari anomaly, and Takayasu's disease [2, 3, 20].

Symptomatic treatment is prescribed for patients with KA [2, 6]. The efficacy of treatment varies from 40% to 98%, and the disease relapse rate reaches 60%. Treatment includes myorelaxants, venotonics, nootropic drugs, calcium channel blockers, nonsteroidal anti-inflammatory drugs, and anticonvulsants. Acupuncture,

injection of botulinum toxin type A, and blockade may be performed.

Despite the prevalence of the disease, studies on surgical treatment are limited [1, 20, 21]. Surgical treatment is mainly indicated for disease progression, ineffective conservative treatment methods, and decreased blood flow velocity along the vertebral artery [1–3].

In our study, all patients at the outpatient stage underwent spondylography of the cervical spine, angioregime CT, and ultrasound with functional tests. These were performed by an ENT, a neurologist, and an ophthalmologist. We observed a direct correlation between the severity of the patients' condition according to Gulyaev's scale and impaired blood flow through the vertebral artery on the KA side. Thus, patients with grade II and III severity according to Gulyaev's scale showed a statistically significant (p <0.05) decrease in blood flow during functional tests on the side affected by KA. Patients with grade I experienced a decrease in blood flow along the vertebral artery during functional tests; however, the decrease was not statistically significant (p >0.05).

Chertkov et al. [5] reported the surgical treatment of 17 individuals with KA aged 18–47 years. Following decompression surgery on the vertebral artery, 90% of the patients experienced regression of general cerebral symptoms, 87% experienced a reduction in dizziness and staggering, and 100% experienced a reduction in syncope. Duplex scanning data showed that 95% of patients regained normal blood flow parameters along the vertebral artery. In the control group, 15 patients received conservative therapy instead of surgical treatment; however, their condition did not significantly improve. According to the data from duplex scanning of the vertebral artery, the symptoms of the disease and blood flow velocity remained at the same level. Additionally, three patients lost their ability to work during the study period.

Krylov et al. [1] presented data on the surgical treatment of six patients with symptomatic KA. The authors reported a positive outcome of the disease following microsurgical decompression of the vertebral artery on the side affected by KA, resulting in regression of vertebral–basilar insufficiency and headache in all study participants.

CONCLUSIONS

Microsurgical decompression of the V3 segment is a safe and effective treatment for symptomatic KA. However, careful patient selection, differential diagnosis, and consultation with allied specialists are crucial.

Patients with KA may develop clinical manifestations without a statistically significant decrease in the vertebral artery blood flow velocity.

Access does not affect disease outcomes but correlates with the duration and severity of pain syndrome in the postoperative period.

The use of video endoscopy enables a decrease in the size of the postoperative incision from 12 to 4 cm. This reduction facilitates the early mobilization and discharge of patients from the hospital. In cases where the surgical field is limited, the endoscopic technique permits decompression of the vertebral artery in areas that are not visible under microscopic view.

ADDITIONAL INFORMATION

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Authors' contribution. *A.G. Vinokurov, A.A. Kalinkin, A.A. Bocharov* — surgical treatment, data collection and statistical analysis, manuscript writing, research concept and design, manuscript editing; *G.M. Yusubalieva, O.N. Kalinkina* — collecting and processing material, writing a manuscript. The authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work.

ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

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Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

Вклад авторов. *А.Г. Винокуров, А.А. Калинкин, А.А. Бочаров* — проведение оперативного лечения, сбор и статистический анализ данных, написание рукописи, концепция и дизайн исследования, редактирование рукописи; *Г.М. Юсубалиева, О.Н. Калинкина* — сбор и обработка материала, написание рукописи. Авторы подтверждают соответ-

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ствие своего авторства международным критериям ICMJE (все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией).

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AUTHORS' INFO

The author responsible for the correspondence:
Aleksandr A. Kalinkin, MD, PhD;
address: 28 Orekhovy boulevard, 115682 Moscow, Russia;
ORCID: 0000-0002-1605-9088;
eLibrary SPIN: 9919-5834;
e-mail: aleksandr_kalinkin27@mail.ru

Co-authors:
Aleksey G. Vinokurov, MD, PhD;
e-mail: avinok@yandex.ru

Andrey A. Bocharov, MD, PhD;
ORCID: 0000-0001-8970-3762;
e-mail: nsi7@mail.ru

Anton V. Yarikov, MD, PhD;
ORCID: 0000-0002-4437-4480;
eLibrary SPIN: 8151-2292; e-mail: anton-yarikov@mail.ru

Gaukhar M. Yusubalieva, MD, PhD;
ORCID: 0000-0003-3056-4889;
eLibrary SPIN: 1559-5866; e-mail: gaukhar@gaukhar.org

Olga N. Kalinkina;
ORCID: 0000-0001-5538-904X;
e-mail: sunny1917@mail.ru

ОБ АВТОРАХ

Автор, ответственный за переписку:
Калинкин Александр Александрович, к.м.н.;
адрес: Россия, 115682, Москва, Ореховый бульвар, д. 28;
ORCID: 0000-0002-1605-9088;
eLibrary SPIN: 9919-5834;
e-mail: aleksandr_kalinkin27@mail.ru

Соавторы:
Винокуров Алексей Георгиевич, к.м.н.;
e-mail: avinok@yandex.ru

Бочаров Андрей Александрович, к.м.н.;
ORCID: 0000-0001-8970-3762;
e-mail: nsi7@mail.ru

Яриков Антон Викторович, к.м.н.;
ORCID: 0000-0002-4437-4480;
eLibrary SPIN: 8151-2292; e-mail: anton-yarikov@mail.ru

Юсубалиева Гаухар Маратовна, к.м.н.;
ORCID: 0000-0003-3056-4889;
eLibrary SPIN: 1559-5866; e-mail: gaukhar@gaukhar.org

Калинкина Ольга Николаевна;
ORCID: 0000-0001-5538-904X;
e-mail: sunny1917@mail.ru

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