Original article

The Keyhole Approach in Anterior Circulation Aneurysm – Current Indication and Limitation with Review of Literature

Abstract

Introduction: The keyhole approach has been an emerging technique for cerebral aneurysm surgery in the past two decades. The preoperative simulation and tailored-made approach for each patient make feasible to clip many cerebral aneurysms via keyhole approach. In our study, we reviewed the previous experiences of the keyhole approach, related specifically for anterior circulation aneurysm. **Material and Methods:** The comprehensive literature review was performed on PubMed, Google Scholar, ScienceDirect, and various neurosurgery and neurology journals. Then, each manuscript's reference list was reviewed for the potential relevant article. The data of total 17 articles, which met our inclusion criteria included for the final review. **Results:** It was found that the anterior communicating artery, middle cerebral artery, and internal carotid- posterior communicating aneurysms were the most common locations treated by keyhole approach. The size of an aneurysm was <10 mm in most of the studies. Many studies treated multiple aneurysms by single keyhole approach. **Conclusion:** The keyhole approach has shown benefit in term of satisfactory aneurysmal occlusion rate, short operative time, less blood loss, short hospital stay, and good overall surgical outcome.

Keywords: *Commonest anterior circulation aneurysm treated by keyhole approach, complete occlusion rate, hospital stay, keyhole approach for anterior circulation aneurysm*

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Introduction

The anterior circulation aneurysm surgery was started with the Dandy frontotemporal approach in neurosurgery. Then, Yasargil's microsurgical pterional craniotomy approach gains popularity in aneurysm surgery.[1] The pterional craniotomy approach is highly versatile and one of the most commonly utilized cranial approaches, but it has certain limitations such as temporal muscle atrophy and damage to a frontal branch of facial nerve. The improvement in diagnostic tools enables three-dimensional (3D) reconstruction of anatomy and pathological orientation, which enable for the concept of keyhole approach to minimize tissue trauma and to maximize surgical outcome.[2] The advances in neuromicroscope, endoscope, neuronavigation, and neuromonitoring tools further add in safety of keyhole approach. However, the keyhole approach cannot be applied for every anterior circulation aneurysm. The controversies exist regarding the use of this approach in different aneurysm location, optimal aneurysm size, and in the patient with subarachnoid hemorrhage. In this article, the current concept and proper patient selection for approach have been discussed with the review to summarize the reported experience on the keyhole approach specifically in anterior circulation.

Materials and Methods

The PubMed, Google Scholar, ScienceDirect, and various neurosurgery and neurology database were searched for literature regarding keyhole approach in anterior circulation aneurysm. The search term "supraorbital keyhole anterior circulation aneurysm," "pterional keyhole anterior circulation aneurysm," and "keyhole anterior circulation aneurysm" were applied. Only literature published in English was reviewed. The references of literature were searched manually for article specific for anterior circulation on keyhole approach. The article mentioning a modified keyhole approach, posterior circulation aneurysm, and an intracranial tumor was excluded from the study. The publication by the same author in the subsequent year with similar aneurysm data and keyhole

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How to cite this article: Rathore L, Yamada Y, Kawase T, Kato Y, Senapati SB. The keyhole approach in anterior circulation aneurysm – Current indication and limitation with review of literature. Asian J Neurosurg 2020;15:278-84.

Submitted: 28-Jan-2019 **Accepted:** 30-Sep-2019
Published: 29-May-2020

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Access this article online

Website: www.asianjns.org

DOI: 10.4103/ajns.AJNS_25_19

Quick Response Code:

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approach method has been excluded in view of overlap in the patient population. The data were extracted from 17 publications and a descriptive analysis of data was done.

Results

A total of 17 publications, which includes 1777 surgically treated aneurysm of anterior circulation by keyhole approach, met our inclusion criteria. The total number of patients in 17 studies was 1597, out of which aneurysms were unruptured in 534 cases and ruptured in 936 cases. In two studies which include 127 cases, aneurysmal ruptured or unruptured status was not specified. The keyhole approaches used in studies were supraorbital, pterional, and superolateral keyhole approach [Table 1]. The aneurysms of the anterior communicating artery (n = 591) and middle cerebral artery (MCA) (n = 577) were the most frequent aneurysms to be treated by the keyhole approach in our study. The internal carotid-posterior communicating (IC-PC) artery aneurysm (n = 335) was the most common location among aneurysm of an IC artery. In our review of case series, the multiple aneurysms were treated in single-stage operation in 11 of studies. The number of cases with multiple aneurysms was range from minimum 2 cases to a maximum of 41 cases in the different study [Table 1]. The size of an aneurysm was described differently in different case series. It was mentioned <10 mm size from minimum 89.2% cases to 100% cases in four studies [Table 1].[2-5] In the study of 102 cases by Park *et al*., the mean size of an aneurysm was mentioned 6.1 ± 2.6 mm in size.[6] Caplan *et al*. mentioned average size of the aneurysm 5.45 mm in the case series of 72 patients.[7] The complete occlusion of an aneurysm was mentioned in 12 case series, which range from minimum 92% cases to maximum 100% cases [Table 2]. Yu *et al*.[8] and Tang C *et al*.,[9] reported a complete occlusion rate of the aneurysm in 97.87% and 94% respectively in their case series. The intraoperative rupture of an aneurysm had

Table 1: Anterior circulation aneurysm characteristics on study of keyhole approach

Study	Number of patients/number of aneurysm	R/U	Keyhole approach	Acom and ACA	MCA	ICA	Multiple	Size of aneurysm
Figueiredo *et al*., 2016[2]	86/102	37/49	PKA	Acom-28	40	ic-pc-31, ic-ac-8, ic-oa-2, ic-bi-3	16	<10 mm 90.1%
Mori *et al*., 2017[3]	151/260	0/151	PKA + SKA	Acom-63	150	ns-47	31	<10 mm
Mori *et al*., 2018[4]	63/63	0/63	SLKA	Acom-63	0	0	12	<10 mm
Chalouhi *et al*., 2013[31]	87/87	NS	SKA + PKA	Acom-51	0	ic-pc-26, ic-oa-7, ic-bi-3	NA	<12 mm 80%
Mitchell *et al*., 2005[5]	47/56	6/41	SKA	0	40	ic-pc-13, ic-ac-1, ic-bf-2	6	<10 mm (89.2%)
Tang *et al*., 2018[12]	356/408	356/0	PKA	Acom-118, aca-18	50	ic-pc-105, ic-ac-9, ot-26	41	<2.5 cm
Park *et al*., 2011[6]	102/120	0/102	SKA	Acom-21, A1-7	56	ic-pc-23, ic-ac-8, ot-5	17	Mean - 6.1±2.6 mm
Caplan *et al*., 2014[7]	72/82	0/72	PKA	0	36	ic-pc-22, ic-ac-1, ic-oa-22, ot-1	7	Avg-5.45 mm
Bhatoe *et al*., 2009[13]	52/55	52/0	SKA	Acom-25, A1-1	11	ic-pc10, ic-bi-5	4	Range - 4-12 mm
Tra *et al*., 2018[15]	25/28	25/0	PKA + SKA	Acom-11	13	ns-4	2	Range - 2-6 mm (22 patients)
Yamahata *et al*., 2014[14]	103/111	57/46	PKA	Acom-29	51	ns-31	8	Mean-5.8±2.2mm
Cheng *et al*., 2006[11]	40/40	NS	PKA	Acom-9, aca-1	10	ic-pc-14, ic-oa-3, ot-3	NA	NA
Chen *et al*., 2009[10]	88/88	88/0	SKA	Acom-41	29	ic-pc-18	0	<15 mm 100%
Tang *et al*., 2013[9]	76/80	70/6	SKA	Acom-33, A1-4	17	ic-pc-14, ic-oa-3, ot-2	4	Range - 5-19mm
Sharma *et al*., 2015[30]	14/14	10/4	SKA + PKA	Acom-7	4	ic-pc-1, ic-bi-2	0	NA
Yu *et al*., 2015[8]	47/47	47/0	PKA	Acom-10, aca-3	19	ic-pc-15	0	<20 mm
Park *et al*., 2018[16]	188/188	188/0	SKA	Acom-82	51	ic-pc-44, ic-ac-2, ic-oa-1, ic-bi-3	0	Avg-5.5 mm
Total	1597/1777	936/534		Acom-591, aca-34	577	ic-pc-335, ic-ac-29, ic-oa-38, ic-bi-16, ot-37, ns-82		

R – Ruptured; U – Unruptured; Acom – Anterior communicating artery; ACA – Anterior cerebral artery; MCA – Middle cerebral artery; ICA – Internal carotid artery; SKA – Supraorbital keyhole approach; PKA – Pterional keyhole approach; SLKA – Superolateral keyhole approach; ic-pc – Internal carotid-posterior communicating artery aneurysm, ic-ac – Internal carotid-anterior choroidal artery aneurysm, ic-oa – Internal carotid-ophthalmic artery aneurysm, ic-bi – Internal carotid artery bifurcation aneurysm, ot – Other internal carotid artery aneurysm, NS – Not specified internal carotid artery aneurysm; NA – No data available; Avg – Average

Table 2: Outcome of keyhole approach surgery on anterior circulation aneurysm

Study	Complete occlusion (%)	Number of intraoperator rupture	Operation time	Blood loss	Hospital stay	GOS	mRS	Frontalis weakness
Figueiredo *et al*., 2016[2]	97.05	5	NA	NA	NA	NA	0-1 (79.9%)	NA
Mori *et al*., 2017[3]	96	NA	Nonelderly - 177±39 min, elderly - 171±36	NA	Nonelderly - 2.7±4.7, elderly - 2.2±0.8 days	NA	Nonelderly - 0.0±0.3, elderly - 0.0±0.2	NA
Mori *et al*., 2018[4]	98.40	1	198±37 min	NA	2.4±2.2 days	NA	3 month - 0 and 1 all. (MMSE <24%-1.6%)	3
Chalouhi *et al*., 2013[31]	NA	6	PKA - 256 min, SKA - 205 min	NA	NA	5-4 (75%) 1 year	NA	NA
Mitchell *et al*., 2005[5]	NA	2	NA	NA	NA	NA	NA	NA
Tang *et al*., 2018[12]	93.60	NA	160±57 min	204±100 ml	8.32±2.72 days	NA	6 month - 0-2 (71.1%)	NA
Park *et al*., 2011[6]	98.30	NA	120±30 min	No tranfusion	NA	NA	NA	6
Caplan *et al*., 2014[7]	NA	NA	NA	NA	3.96 days	NA	NA	NA
Bhatoe *et al*., 2009[13]	47 pts-100	12	NA	NA	43 patients - 7 days	NA	NA	1
Tra *et al*., 2018[15]	100	2	NA	NA	NA	Dis - 5-4 (96%)	NA	NA
Yamahata *et al*., 2014[14]	100	10	NA	NA	NA	5-3 (44.6%)	NA	6
Cheng *et al*., 2006[33]	NA	3	NA	NA	NA	NA	NA	NA
Chen *et al*., 2009[10]	92.00	23	NA	NA	NA	1 year - 5-4 (88.6%)	NA	NA
Tang *et al*., 2013[9]	94.00	8	NA	NA	NA	Dis - 4-5 (95%)	NA	0
Sharma *et al*., 2015[30]	100	1	NA	NA	NA	NA	NA	NA
Yu *et al*., 2015[8]	97.87	NA	NA	NA	NA	NA	NA	NA
Park *et al*., 2018[16]	NA	17	NA	NA	NA	NA	Dis - 0%-28.2%, 1%-49.5%	0

GOS – Glasgow outcome scale, mRS – Modified Rankin score, Dis – Discharge, NA – No data available; MMSE – Mini-mental status examination

been mentioned in 12 studies in certain cases, mostly either during perianeurysmal dissection or during clip application [Table 2]. In the case series Chen *et al*.,[10] of total 88 ruptured aneurysm cases they reported 23 intraoperative rupture. The Cheng *et al*.,[11] reported 3 cases of intraoperative rupture out of a total of 40 cases in their case series.

The mean operative time was studied in five case series, and it was varied from 120 ± 30 min to 256 min [Table 2]. The case series with a large number of cases mentioned less operative time.[3,6,12] Tang *et al*. reported mean blood loss of 204 ± 100 ml in a study of 356 cases.[12] Park *et al*. reported no requirement of blood transfusion in operation of 102 cases.[6]

Mori *et al*. reported mean hospital stay of 2.4 ± 2.2 days in the study of 63 unruptured aneurysm cases.[4] Caplan *et al*. reported average hospital stay of 3.96 days in the case series of 72 patients with the unruptured aneurysm.[7] In case series of Bhatoe, 43 patients with the ruptured aneurysm (out of a total of 52 cases) discharged within 7 days of operation.[13] Tang *et al*. reported a mean hospital stay of 8.32 ± 2.72 days in the study of 356 ruptured aneurysm cases.[12]

The Glasgow outcome scale was measured in five studies. Yamahata *et al*. reported good outcome (grade 5–3) in 44.6% cases, in a series which includes both ruptured and unruptured aneurysm.[14] Tra *et al*. reported the Glasgow Outcome Scale of Grade 5–4 in 96% of cases at the time of discharge.[15]

In the study of Mori *et al*., mean mRS was 0.0 ± 0.3 (nonelderly) and 0.0 ± 0.2 (elderly) in two different cohort groups with unruptured anterior circulation aneurysm.[3] Tang *et al*. reported mRS of 0–2 in 71.1% of cases in 6 months follow-up period.[12] Mori *et al*. reported a good outcome (mRS 0–1 all patients) in 3 months follow-up period.[4] Park *et al*. reported mRS of grade 0 in 28% cases and Grade 1 in 49.5% of cases.[16]

The frontalis weakness has been reported in four studies.[4,9,12,13] Park *et al*. and Yamahata *et al*. reported frontalis weakness in 6 cases out of total 102 patients and 103 patients, respectively, in their case series.[6,13]

Discussion

Keyhole approach for anterior circulation aneurysm-why needed?

The surface lesion in the brain requires big craniotomy often larger than pathology. In deep-seated skull base lesion like an aneurysm, the size of traditional craniotomy is much larger than primary pathology. The large craniotomy exposed larger brain surface area, more soft tissue, and bony area. The greater exposure as compared to the size of pathology increases morbidity related to each tissue disruption from normal anatomy. The goal of the keyhole approach is to limit trauma to surrounding structure such as the skin, muscle, bone, dura, and brain.[1] The deep-seated lesion in the brain can be treated by small craniotomy because it forms "reverse funnel-shaped surgical corridor" with a wide operative field.[17] Then, the evolution in endovascular procedure with a lower complication rate and satisfactory aneurysm treatment, further inspire the surgeon to develop less morbid surgical options for aneurysm surgery. The advantages of keyhole approach are small operative wound, short operative duration, less blood loss, negligible damage to temporalis muscle, and less wound-related pain which ultimately leads to early return in productive life of patient.[18]

History and evolution of the keyhole approach

History of cerebral aneurysm treatment starts by Victor Horsley's ligation of common carotid artery for an ipsilateral cerebral aneurysm in 1855. Normann Dott did first wrapping of a cerebral aneurysm in 1933.[19] The application of V-shaped silver clip done by Walter Dandy in the year 1935.[20] Then, Gazi Yasargil started use of the microscope in 1960.[21] Donald H Wilson in 1971 first used keyhole surgery term as an extension of trephination. John Jane described modified supraorbital approach with minimal brain retraction in 1982.[22] In the late 1980s, the indication and concept of keyhole approach established by Paladino *et al*.[23]

The principle keyhole approach described for anterior circulation aneurysm is: (1) superciliary supraorbital craniotomy, (2) lateral supraorbital craniotomy, and (3) mini-pterional craniotomy.

The indication of a keyhole approach in anterior circulation aneurysm

The superciliary keyhole approach can be applied in an aneurysm with maximum diameter <15 mm arising at or below the level of horizontal segments of anterior cerebral artery and MCA.[6] An aneurysm at supraclinoid internal carotid artery (ICA), A1, ACoA, M1, and MCA bifurcation are normally favorable for clipping by keyhole approach [Table 3].[18] In case of ICA aneurysm, PC and anterior choroidal artery aneurysm, which arise at the lateral or posterior-lateral wall of an ICA can be clipped by the superciliary approach. In case of posterior wall ICA aneurysm, a larger craniotomy and angled fenestrated clip may be necessary. The location of an aneurysm in low lying supraclinoid or paraclinoid ICA that require drilling of the anterior clinoid process also need larger craniotomy. However, an orbital osteotomy combined with supraorbital minicraniotomy can facilitate drilling work.[18]

The inferior and anterior directing anterior communicating aneurysm can be clipped by the superciliary approach. The superior-directing and high-positioned anterior communicating artery aneurysm may require a pterional transylvian approach.[18] The posterior directing large anterior communicating artery is a challenging case, may require anterior interhemispheric approach. The A1 portion of an aneurysm can be clipped by the superciliary approach.

An aneurysm arising from M1 and MCA bifurcation can be clipped using the keyhole approach.[15] If an aneurysm located beyond MCA genu, a larger cranial opening is needed. The wide neck MCA aneurysm, which needs clip application in multiple directions, will need larger craniotomy for multiple axis movements.

Mori *et al*. reported the experience of 260 unruptured aneurysms of anterior circulation in total 151 patients, out of which 63 were Acom aneurysms, 150 MCA aneurysms, and 47 ICA aneurysms. They emphasize to use keyhole approach for unruptured aneurysm cases. In ruptured aneurysm cases, brain swelling and subarachnoid hemorrhage clot hinder the operative view and manipulation so should be avoided.[3]

Table 3: Indication and contraindication of keyhole approach in anterior circulation aneurysm

Aneurysm location	Indication	Relative or absolute contraindication
ICA	Pcom, especially including 3CN palsy	Posterior wall ICA aneurysm
	AChA aneurysm (without perforator involvement behind the neck)	Low lying supraclinoid ICA aneurysm
	ICA bifurcation aneurysm	
	Dorsal wall ICA aneurysm	
ACA	A1 segment aneurysm	Superior- or posterior-directing large Acom aneurysm
	Inferior or anterior directing Acom aneurysm	High-positioned Acom aneurysm
		Pericallosal artery aneurysm
MCA	M1 segment aneurysm	Aneurysm distal to MCA genu
	MCA bifurcation aneurysm	Short M1 and posteriorly projecting aneurysm

ICA – Internal carotid artery; MCA – Middle cerebral artery; ACA – Anterior cerebral artery; AChA – Anterior choroidal artery

In our review, the size of aneurysms was small in most of the case series. It was <10 mm size in case series of Mori *et al*. (100% cases),[3,4] Figueiredo *et al*. (90.1% cases),[2] and Mitchell *et al*. (89.2%).[5]

The mean size of an aneurysm reported by Park *et al*. in the study of 120 aneurysms of anterior circulation was 6.1 ± 2.6 mm.[6] Similarly, Yamahata *et al*. reported a mean size of an aneurysm in their study was 5.8 ± 2.2 mm.[14]

Role of endoscopy in keyhole anterior aneurysm surgery

Neuroendoscopy has been used in the treatment of a cerebral aneurysm in the early 1990s. The advantage of endoscopy in keyhole surgery is strong illumination, a clear depiction in close up view and wide viewing angle. In addition, when using the holding arms, bimanual manipulation is possible.[24] The hidden angle with straight line microscopic view can be clear with endoscopy in small craniotomy of keyhole approach. The evolution of endoscopic indocyanine green video angiography further adds up the advantage of endoscopy in the field of aneurysm surgery. Compared to conventional endoscopy, endoscopic indocyanine green angiography (ICGA) can visualize ICG fluorescence within small perforator, parent artery, and clipped an aneurysm beyond the line of microscopic view.[25] The angled lenses also allow visualization around corners without requiring retraction of the important neurovascular structure. The secondary advantage with the endoscope is improved ability to achieve hemostasis, which is difficult through keyhole approach.[26]

The advantage of the keyhole approach in anterior circulation aneurysm

Minimal soft-tissue damage and a better cosmetic outcome

The advantage of the keyhole approach is its minimal invasiveness. The approach provides satisfactory aneurysm clipping with minimal soft-tissue damage. The technique of minimal invasiveness protects the amount of normal brain tissue exposed by environmental contact. The keyhole approach has a cosmetically pleasant small incision. The atrophy of temporal muscle and paralysis of frontalis are rare with keyhole approach and can be avoided with less skin retraction. The blood supply of the supraorbital region is good, and there is less wound-healing problem.[27]

Mori *et al*. reported more than 88.9% cosmetically satisfied patients via lateral supraorbital minicraniotomy in anterior communicating artery aneurysm. The frontalis weakness has been detected in 3 cases out of total 63 patients in case series.[4]

Park *et al*. and Yamahata *et al*. reported frontalis weakness in 6 cases out of total 102 and 103 patients in their case series, respectively.[6,14]

Occlusion rate

The occlusion rate of aneurysm treatment by open surgical procedure remains superior to endovascular treatment.[28] The treatment of an unruptured aneurysm by endovascular approach reported complete occlusion in 59%, neck remnant in 21.7%, and aneurysm remnant in 19.3% of cases.[29] In general, aneurysm recanalization occurs more frequently with endovascular treatment than clipping. In our review, good complete occlusion rate of aneurysms has been reported with keyhole approach.

The aneurysmal occlusion rate of 100% reported by Yamahata *et al*. (103 cases),[14] Tra *et al*. (25 cases),[15] and Sharma *et al*. (14 cases).[30]

Mori *et al*. reported occlusion rate of 98.4% out of the total 63 anterior communicating artery aneurysm and neck remnant rate 1.6%. In their study, no aneurysm recurrence observed during follow-up of mean 4.9 years.[4]

Chen *et al*. reported complete occlusion rate of 92% cases out of total 88 patients in their case series.[10]

Less operative time and blood loss

Park *et al*. reported mean operative time of 120 ± 30 min in a study of 102 patients with supraorbital keyhole approach.[6] Mori *et al*. reported mean operative time of 198 ± 37 min in 63 anterior communicating artery aneurysm cases via superolateral orbital keyhole approach.[4]

Chalouhi *et al*. reported average operative time for pterional keyhole approach 256 min and 205 min for supraorbital keyhole approach cases.[31]

In the study of Park *et al*., no requirement of blood transfusion has been mentioned in 102 patients operated by keyhole craniotomy approach.[6] Tang *et al*. reported average blood loss of 204 ± 100 ml in operation by keyhole approach in 356 cases.[12]

Minimizing hospital stay

The keyhole approach reduces hospital stay as compared to traditional craniotomy (7.4 days) and matches to that of endovascular surgery (4.5 days).[32] Mori *et al*. reported mean hospital stay of 2.7 ± 4.7 days in nonelderly and 2.2 ± 0.8 days in the elderly group of patients.[3] Caplan *et al*. reported average hospital stay of 3.96 days in their study of 72 patients.[7]

Bhatoe reported the discharge of 43 cases out of total 52 patients within 7 days of operation.[13] Tang *et al*. reported the mean hospital stay of 8.32 ± 2.72 days in the study of 356 patients.[12]

Quality of life

The ISUIA study showed impaired cognitive function (mini-mental status examination [MMSE] score <24) were higher with surgical clipping (8.5%) than endovascular coiling (5.4%).[33] Mori *et al*. reported mRS 0–1 in all 63 cases at 3 months follow-up and MMSE score <24 in only 1.6% of cases. They mentioned that improved outcome may be due to the absence of surgical contusion

and avoidance of ischemia and hemorrhagic complication in keyhole approach.[4]

Park *et al*. reported mRS of 0 in 28.2% cases and 1 in 49.5% cases at the time of discharge in their study.[16] Chalouhi *et al*. reported Glasgow outcome scale of 5–4 in 75% cases within 1-year follow-up.[31]

The limitation of the keyhole approach in anterior circulation aneurysm

The predefined surgical corridor

The corridor of dissection cannot be changed during surgery. The preoperative information regarding exact location and size of mini-craniotomy to determine precise trajectory is an essential part of the keyhole approach. The tailor-made keyhole surgery with computer simulation using 3D computed tomography angiography is useful. The various shapes and sizes of virtual mini-craniotomy can be generated by modern work station to visualize target lesion through the keyhole.[17] According to individual pathoanatomy and individual surgeon experience, tailor-made craniotomy useful in the success of keyhole surgery.

Decreased intraoperative orientation

The small working space may create confusion in understanding neuroanatomy intraoperative. The use of navigation tools may assist in proper intraoperative identification of structure. The detailed knowledge of individual pathoanatomy before surgery is necessary to avoid such confusion.[31]

Narrow viewing angle and coaxial control of instrument

The craniotomy small as 20–25 mm create a narrow viewing angle and difficulty in manipulating multiple instruments. The instrument with the tubular shaft of scissor, clip applicator, bipolar, and grasping forceps essential for keyhole approach.[34]

Loss of intraoperative light and sight

The small craniotomy with bimanual hand movement may create a loss of microscope light in the operative field. The illumination at deep may not be good with a microscope. The endoscope should be used to improved illumination and visualization in deep or angle space in the operative field in keyhole approach.[35]

Large frontal sinus

The huge frontal sinus coming in planned craniotomy site of keyhole approach are a contraindication for supraorbital keyhole surgery. The sinus repair with the pericranial patch is not possible with supraorbital keyhole approach.[17]

Conclusion

The keyhole approach evolved as a minimally invasive surgical approach for anterior circulation aneurysm. In our review of case series, the keyhole approach had been used commonly in surgery of Acom, MCA, and IC-PC aneurysm. The aneurysm size was small in most cases in all reviewed case series. The keyhole approach has been used successfully in multiple aneurysm cases in a single-stage procedure. Satisfactory complete aneurysmal occlusion rate has been reported by keyhole approach. The approach may be most suitable for small, proper orientation, preferably unruptured aneurysm of anterior circulation. The technique has the advantage of minimally invasive approaches such as short operative time, less blood loss, and short hospital stay. The long-term outcome of keyhole approach is lacking at present. In future, further modification in the surgical instrument, computer simulation, and advance microscope may further improve the safety of the procedure.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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