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Minimally Invasive Approaches in Reoperations after Conventional Craniotomies : Case Series

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Objective : Reoperations are part of neurosurgical practice. In these cases, an already formed craniotomy seems the most logical and appropriate. However, reoperations via large approaches can be quite traumatic for the patient. Then minimally invasive approaches, being less traumatic, can be a good alternative.

Methods : We describe seven consecutive patients who underwent reoperations using minimally invasive approaches in the areas of conventional craniotomies. Surgical Theater® visualization platform was used for preoperative planning. The study evaluated the size of surgical approach, surgical efficacy, and the presence of complications.

Results : The size of a minimally invasive craniotomy was significantly smaller than that of a conventional approach. The preoperative goals were achieved in all described cases. There were no complications in the early postoperative period. Although the anatomy of the operated brain region in reoperations is altered, keyhole approaches can be successfully used with the support of preoperative planning and intraoperative neuronavigation. Given that the goals of reoperations may differ from those of the primary surgery, and a large approach is more traumatic for the patient, minimally invasive craniotomy can be considered as a good alternative. The successful use of minimally invasive approaches in areas of conventional craniotomies reinforces the philosophy of keyhole neurosurgery. In cases where goals can be achieved using small approaches, it makes no sense to use large conventional ones.

Conclusion : Minimally invasive approaches can be successfully used during reoperations in patients after conventional craniotomies.

Key Words : Minimally invasive surgical procedures · Reoperation · Keyhole.

INTRODUCTION

The concept of minimally invasive neurosurgery or keyhole neurosurgery is to use the smallest possible surgical approach without compromising the quality of surgery and the intra- and postoperative risks[14,16].

Many factors contribute to the development of minimally invasive neurosurgery, which is becoming a greater alternative to conventional approaches with each passing year. First of all, there is acquired practical knowledge based on many years of

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neurosurgeons' experience. The most famous supporters of keyhole approaches are such neurosurgeons as D. Wilson and A. Pernetzky[6,15,18].

The surgical microscope is an indispensable aid that makes operations through small approaches possible. Modern microscopes not only have good optical systems, but they are also very easy to operate, which allows the neurosurgeon to perform operations comfortably for long hours[10,17].

Neuronavigation systems make it possible to navigate with millimeter precision in the operative field[4,8,12]. Neuronavigation helps to plan precisely the craniotomy area, which is the most important thing in the concept of minimally invasive neurosurgery[7,19]. In fact, an incorrectly performed craniotomy will not form a surgical corridor to allow the necessary surgery to be performed. This field is currently undergoing a great deal of development. The use of three-dimensional (3D) virtual reality goggles in preoperative planning and surgery is now possible. This allows the neurosurgeon to study anatomical features in detail in each case and get ready for possible complications during surgery[9].

Intraoperative neuromonitoring is also a very important aid in neurosurgical operations, both at the base of the brain and in other eloquent areas of the brain[3,13].

In neurosurgical practice, there are constantly cases of reoperations for various reasons[1,2,11]. In such cases, the easiest way is to use an already formed surgical approach. Due to the fact that our is specialized on minimally invasive neurosurgery for many years and conventional approaches for conventional surgeries are very rarely used, we also use minimally invasive approaches in those patients who have been operated on via conventional or large craniotomies.

The anatomy of the operated brain region is certainly much altered during reoperations, and this can be challenging for the surgeon. However, given the large arsenal of auxiliary aids described above, it is possible to perform such surgeries successfully. We report a series of consecutive patients who underwent reoperations using minimally invasive craniotomies (MICs) in an already existing craniotomy after various surgeries.

MATERIALS AND METHODS

We describe seven clinical cases of patients who underwent reoperations after conventional craniotomies in our clinic. We used minimally invasive approaches in the areas of previous craniotomies. All patients were informed of various surgical approaches and accepted a minimally invasive approach. This retrospective study was approved by the Ethics Committee of University of Erlangen–Nuremberg (23-196-Br).

Surgical Theater® visualization platform (Surgical Theater Inc, Beachwood, OH, USA) was used for preoperative planning (Supplementary Video 1). For this purpose, preoperative magnetic resonance imaging (MRI) and computed tomography (CT) images were uploaded to the Surgical Theatre® system (Surgical Theater Inc). A 3D reconstruction of the head was made using these images. The pathological process was marked with a specific color for better visualization. The vessels were also marked where appropriate. The size of the craniotomy and the site of the planned minimally invasive approach in the craniotomy region was then evaluated to be the most optimal, not restricting the surgical view and sufficient to perform a successful surgery. In some cases, the surgery was simulated using 3D glasses. All the markers and landmarks used could be applied intraoperatively, which facilitated some steps of the surgical procedure.

The size of the initial craniotomy and the MIC we performed were also evaluated using this system. The study evaluated the size of surgical approach, surgical efficacy, and the presence of complications.

RESULTS

The results are given in Table 1. Despite the small sample size and heterogeneity of this sample, approaches to reoperation on the skull base and on the skull vault should be distinguished. Therefore, all the patients we described can be divided into two groups. Skull base surgeries for recurrent sphenoid wing meningiomas via a minipterional approach were performed in two cases (cases 4 and 8). In both cases we managed to perform complete resection of the recurrent tumors. In the preoperative planning, much attention was paid to the evaluation of the middle cerebral artery within the surgical field. The other group comprised five patients with recurrent tumors and convexity craniotomies (two meningiomas, two oligodendrogliomas, and one glioblastoma). Minimally invasive approaches were performed in the craniotomy regions in all cases. Complete tumor resection was achieved. No postopera-

Table 1. Summary table of all described cases

Case No.	Sex	Age (years)	Tumor type/localisation	Standard craniotomy size (cm^2)	MIC size (cm^2)	Complication	Goals of surgery	Lenght of follow-up
1	F	50	Meningioma WHO I/falx cerebri	50.11	4.10	-	Removal of tumor recurrence	5 years
2	F	44	Oligodendroglioma WHO III/right frontal lobe	36.4	3.84	-	Removal of tumor recurrence	-
3	F	56	Meningioma WHO I/falx cerebri	30.86	4.25	-	Removal of tumor recurrence	4 years
4	F	77	Meningioma WHO I/right sphenoid wing	39.19	4.36	-	Removal of tumor recurrence	3 months
5	F	67	Glioblastoma WHO IV/right frontal lobe	22.97	4.26	-	Removal of tumor recurrence	1 year
6	F	58	Oligodendroglioma WHO II/right temporal lobe	30.05	5.07	-	Removal of tumor recurrence	2 years
7	F	52	Meningioma WHO I/left sphenoid wing	49.01	5.79	-	Removal of tumor recurrence	2 years

MIC : minimally invasive craniotomy, F : female, WHO : World Health Organization

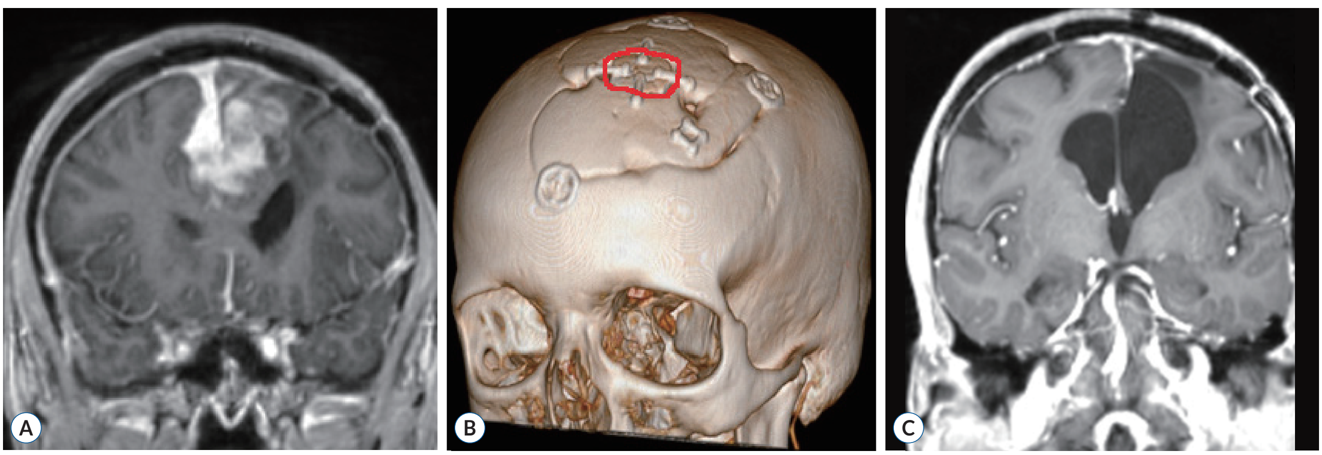

Fig. 1. A 50-year-old female patient with headaches for 4 weeks. A : A follow-up magnetic resonance imaging (MRI) scan shows tumor recurrence in 8 years after the surgery. B : Three-dimensional reconstruction of the cranial vault with a minimally invasive craniotomy (red) in the area of a conventional craniotomy. C : A follow-up MRI scan made 5 years after the reoperation showed no tumor recurrence.

tive complications were reported.

Case 1

A 50-year-old female patient complained of severe worsening headaches for 4 weeks. She was operated on 8 years ago for a large falcine meningioma (World Health Organization [WHO] grade I). An MRI scan showed tumor recurrence with signs of hemorrhage within the tumor (Fig. 1A). A MIC was performed (Fig. 1B). The tumor was completely resected. The follow-up examination made 5 years later showed no tumor recurrence (Fig. 1C).

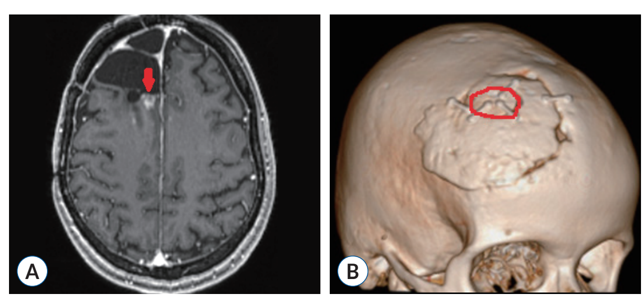

Fig. 2. A 44-year-old female patient with a recurrent oligodendroglioma in the right frontal lobe. A : An axial T1-weighted contrast-enhanced magnetic resonance image shows a small recurrent tumor in the right frontal lobe (red arrow). B : Three-dimensional reconstruction of the cranial vault shows a minimally invasive craniotomy (red) in the area of a conventional craniotomy.

Case 2

A 44-year-old female patient required surgery for a recurrent oligodendroglioma in the right frontal lobe. Ten years ago she was diagnosed with oligodendroglioma (WHO grade III), followed by two reoperations for recurrence. Since the patient had already received radiation therapy and chemotherapy had not stopped the tumor growth, the only alternative left was surgical treatment (Fig. 2A). The MIC was performed, which allowed the recurrent tumor to be resected (Fig. 2B). This case shows that there is no need for large approaches when it comes to small recurrences.

Case 3

A 56-year-old female patient was operated for falcine meningioma (WHO grade I) 20 years ago. She had been followed up at our clinic in the past few years. Over a period of 10 years, her recurrent tumor had been progressing (Fig. 3A). The surgery was indicated based on that. The tumor was completely removed using minimally invasive approach (Fig. 3B). The brain MRI scan made 4 years after the surgery showed no tumor recurrence (Fig. 3C).

Case 4

A 77-year-old female patient had been followed up after the surgery for a right sphenoid wing meningioma (WHO grade I) for 8 years. Due to the progress of a recurrent tumor and its

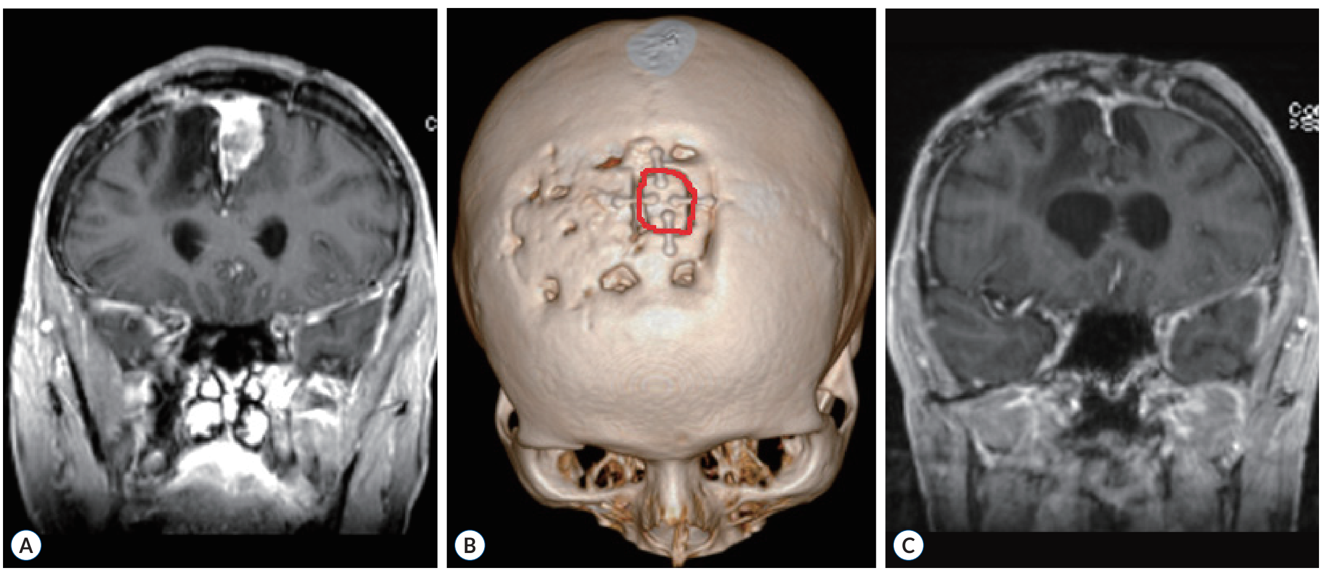

Fig. 3. A 56-year-old female patient with a recurrent falcine meningioma. A : A coronal T1-weighted contrast-enhanced magnetic resonance image shows a recurrent falcine meningioma on the left. B : Three-dimensional reconstruction of the cranial vault with a minimally invasive craniotomy (red). C : A follow-up magnetic resonance imaging scan made 4 years after the reoperation showed no tumor recurrence.

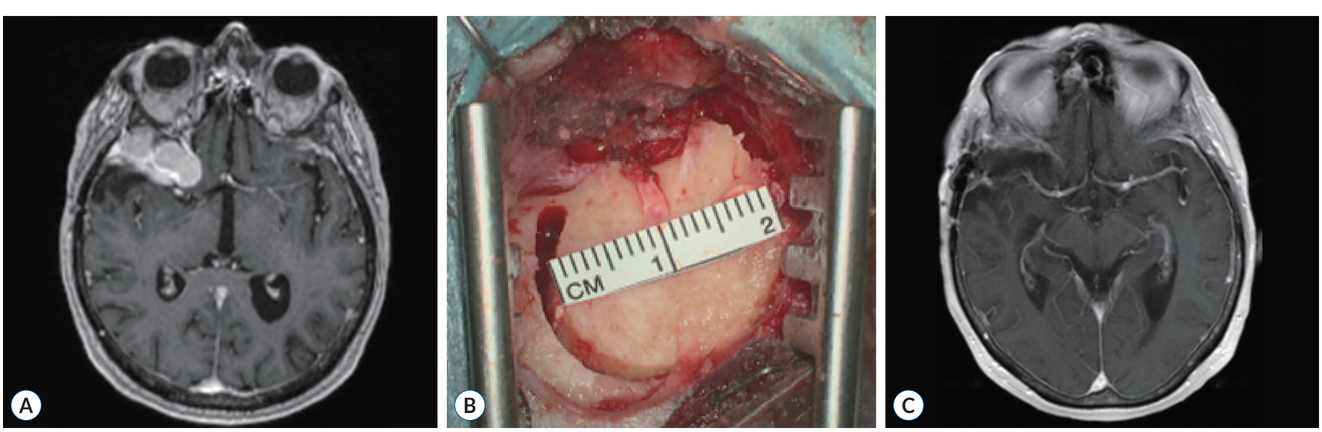

Fig. 4. A 77-year-old female patient with a recurrent right sphenoid wing meningioma. A : A follow-up magnetic resonance imaging (MRI) scan made 8 years after the surgery showed tumor recurrence. B : Intraoperative image of the minimally invasive craniotomy size. C : A follow-up MRI scan made 3 months after the reoperation showed no tumor recurrence.

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contact with the arteria cerebri media, a reoperation was performed (Fig. 4A). The tumor was completely resected (Fig. 4B). No new postoperative neurological deficits were observed. A follow-up MRI scan made 3 months later showed no tumor recurrence (Fig. 4C).

Case 5

A 67-year-old female patient sought a second opinion after being diagnosed with glioblastoma (WHO grade IV). She had undergone a tumor biopsy shortly before (Fig. 5A). Surgery was indicated because of the large tumor size. Total resection was performed (Fig. 5B). Radiation therapy was started 2 weeks after surgery. There was no recurrence 1 year after surgery (Fig. 5C).

Case 6

A 58-year-old female patient with oligodendroglioma (WHO grade II) was found to have a tumor recurrence. She underwent tumor resection 21 years ago, after which she required a reoperation for tumor recurrence 10 years later. After surgical treatment and radiation therapy, there was remission for 11 years. Follow-up MRI and fluoroethyl tyrosine-CT scans showed recurrence, so there was an indication for reoperation (Fig. 6A and B). The MIC was successful (Fig. 6C). A

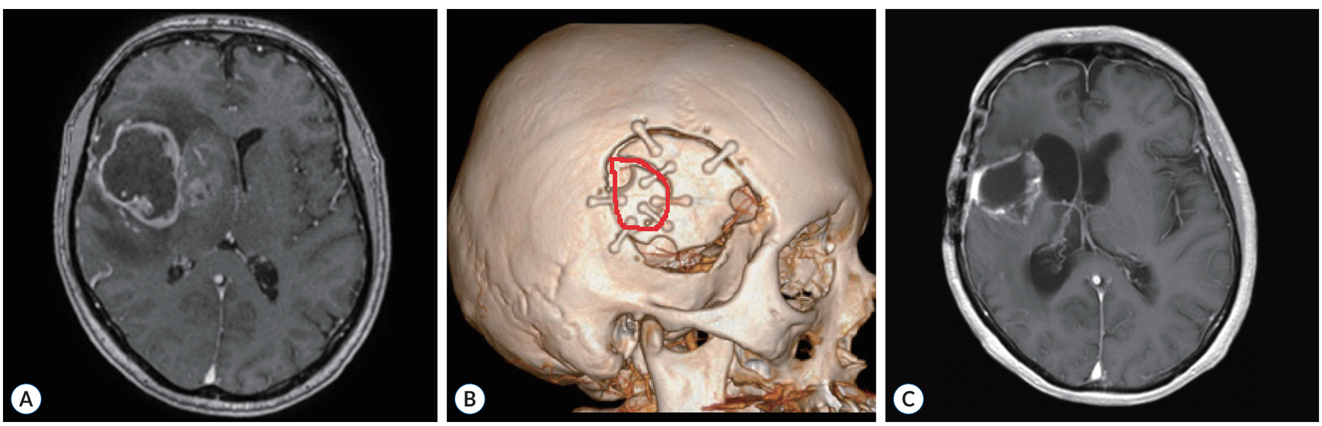

Fig. 5. A 67-year-old female patient with a diagnosed glioblastoma in the right frontal lobe. A : A magnetic resonance imaging (MRI) scan made after a tumor biopsy : an axial T1-weighted contrast-enhanced image shows a large tumor in the right frontal lobe with signs of midline shift. B : Three-dimensional reconstruction of the cranial vault which shows the minimally invasive craniotomy (red) size in the craniotomy area used for the tumor biopsy. C : A follow-up MRI scan made 1 year after the surgery showed no glioblastoma recurrence.

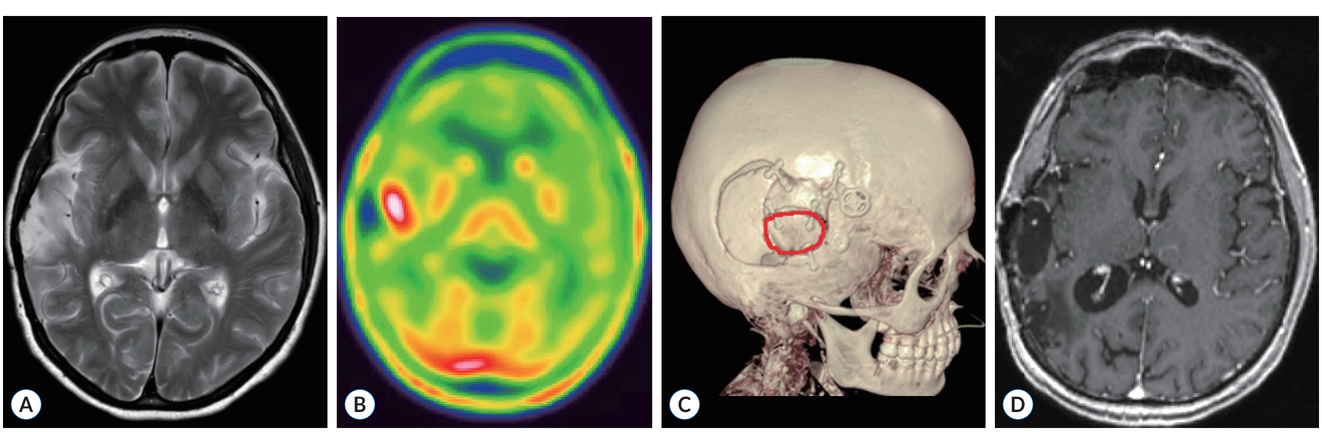

Fig. 6. A 58-year-old female patient with a recurrent oligodendroglioma in the right temporal lobe. A and B : An axial T2-weighted magnetic resonance image and a fluoroethyl tyrosine-computed tomography scan show a recurrent tumor in the right temporal lobe. C : Three-dimensional image of the cranial vault shows the minimally invasive craniotomy (red). D : A follow-up magnetic resonance imaging scan made 2 years after the last surgery showed no tumor recurrence.

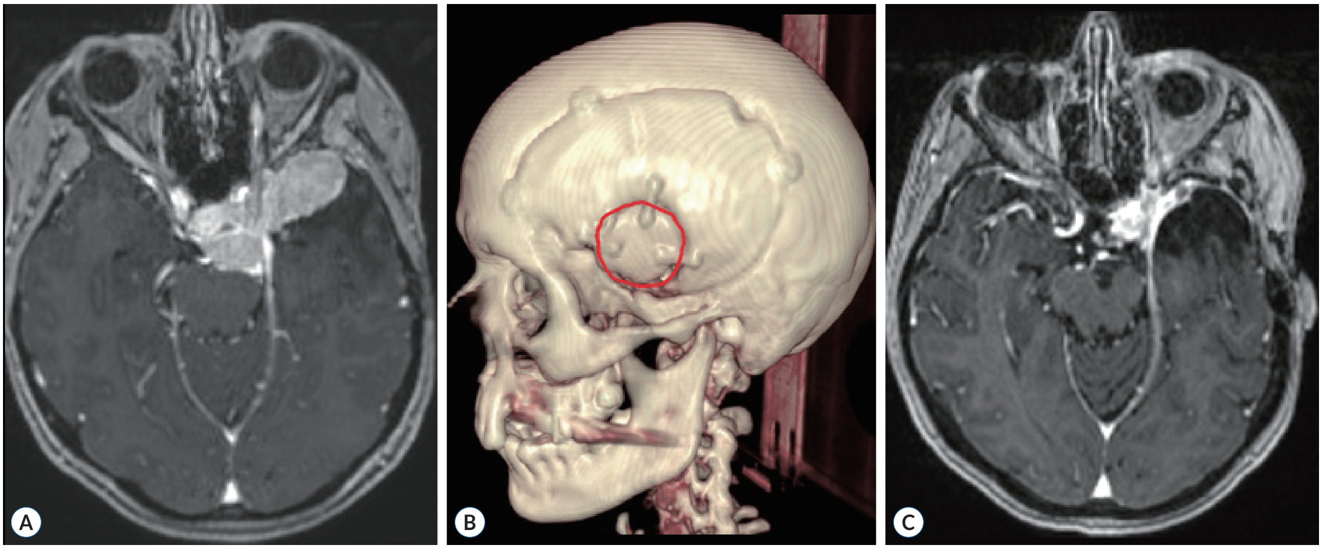

Fig. 7. A 52-year-old female patient with a recurrent left sphenoid wing meningioma. A : A follow-up magnetic resonance imaging (MRI) scan made 11 years after the surgery showed tumor recurrence. B : Three-dimensional reconstruction with a minimally invasive craniotomy (red) image. C : A follow-up MRI scan made 2 years after the reoperation showed no tumor recurrence.

follow-up MRI scan made 2 years later showed no tumor recurrence (Fig. 6D).

Case 7

A 52-year-old female patient had been followed up after subtotal resection of a left sphenoid wing meningioma with cavernous sinus invasion. Tumor recurrence was detected 11 years after the surgery (Fig. 7A). Subtotal resection of the meningioma was performed via MIC (Fig. 7B). Histological examination showed a WHO grade I meningioma. The remnant of the tumor infiltrating the cavernous sinus underwent radiation therapy. A follow-up MRI scan made 2 years later showed no tumor recurrence (Fig. 7C).

DISCUSSION

As the study results show, minimally invasive approaches can be successfully used in the field of conventional craniotomies. This, in turn, significantly reduces surgical injuries.

Irrespective of the fact that the normal anatomy was significantly altered during reoperations, the use of a small approach did not compromise the surgical outcome. All preoperative goals were achieved without changing intraoperative strategies.

In some cases, it can have a significant effect, for example, in patients with aggressive tumors (glioblastomas). Small wounds heal faster, thereby reducing the period before radiation therapy is available (case 5).

It should also be noted that recurrent tumors are often smaller than the initial ones. Therefore, MICs can be performed directly in the areas of recurrent tumors, as cases 2 and 6 demonstrate.

Case 1 shows well the potential of minimally invasive approaches. Indeed, the recurrence tumor size was significant, but its complete removal was possible via a small approach.

The study results confirm the philosophy and concept of minimally invasive neurosurgery. If good results are possible via small approaches in revisions that are more complicated due to the altered anatomy of the operated region, it can be suggested that at least similar primary surgeries could be performed using minimally invasive approaches.

Our study also helps to illustrate the concept of MIC, that is, a craniotomy that is smaller than the conventional one but is sufficient to perform a successful surgery.

At present, there is a lot of discussion concerning the appropriateness of minimally invasive approaches in neurosurgery. The main argument of opponents of keyhole neurosurgery is that with large approaches it is possible to evaluate the anatomy of the operated region in detail and to perform the surgery confidently. However, despite this, the region that the actual tumor resection is performed is always significantly smaller than the exposed part of the brain due to the anatomy of the

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skull and brain. This is especially true for deep seated lesions. In this case, surgical injury and associated complications (cerebrospinal fluid fistulas, impaired wound healing, etc.) are not given much attention.

Opponents of keyhole neurosurgery may argue and ask why a small approach is necessary when there is an already formed craniotomy. But followers of this philosophy and concept could reply – what is a large approach for, when a small one is sufficient and creates substantially less surgical trauma?

However, it should be noted that the use of minimally invasive approaches should be carefully planned. The software, such as Surgical Theatre®, can help with approach planning as well as prevent the development of complications. During reoperation, the major limitation is the altered anatomy. This is especially relevant for skull base approaches, such as a mini-pterional approach. Due to the presence of large vessels and cranial nerves in the recurrent tumor sites, there are risks of severe complications. When using minimally invasive approaches for reoperations, the surgeon always has the option of enlarging the approach by means of the existing craniotomy, which is certainly an advantage.

When minimally invasive approaches are routine practice, even large tumors can be removed through a small approach[5]. Therefore, performing such re-operations is also not a serious problem. All surgical goals were achieved through minimally invasive approach. Considering the fact that it is always possible to use an existing craniotomy, planning and performing a minimally invasive approach does not involve major intraoperative risks.

Limitations

Reoperations using minimally invasive approaches in the region of conventional craniotomies is an alternative surgical technique, the use of which should be carefully considered. Given the altered anatomy of the operated brain region, undesirable complications can occur. The use of such approaches requires basic knowledge of keyhole neurosurgery. At the moment, there is not much experience in this field published in current scientific literature, so it is not possible to evaluate the appropriateness and effectiveness of this approach properly.

CONCLUSION

Minimally invasive approaches can be successfully used during reoperations in patients after conventional craniotomies creating significantly less surgical trauma.

AUTHORS' DECLARATION

Conflicts of interest

No potential conflict of interest relevant to this article was reported.

Informed consent

Informed consent was obtained from all individual participants included in this study.

Author contributions

Conceptualization : DS, GCF, GB, DK; Data curation : DS, GCF, DK; Formal analysis : DS, DK; Methodology : GCF, DK; Project administration : GCF, GB; Visualization : DK; Writing - original draft : DS, DK; Writing - review & editing : GCF, GB

Data sharing

None

Preprint

None

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• Supplementary materials

The online-only data supplement is available with this article at https://doi.org/10.3340/jkns.2024.0085.

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