Robotics for Approaches to the Lateral Skull Base

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7.1 Introduction

This chapter addresses the application of robotics in surgery of the lateral skull base. So far, very few data are available, so much of the chapter will be a theoretical evaluation of the pros and cons of robotics in the main approaches to the lateral skull base.

Historically, the first robotic-assisted procedure in neurosurgery was performed in 1985; it was a brain biopsy. Subsequently, robotic-assisted surgery was applied in many other aspects of neurosurgical practice, initially limited to intracranial and gradually expanding to spinal procedures [1]. Robots, not suffering from fatigue and tremor, improved the accuracy of stereotactic neurosurgical procedures by holding the surgical tools along the line produced by one or more pre-planned trajectories.

Over the following years, the number of publications slowly but continually increased. Nowadays, robot-assisted neurosurgery is used in treating several conditions.

Robotics is considered most helpful for *Stereoelectroencephalography* (SEEG) [2], in which electroencephalographic signals are recorded via deep electrodes. The accurate insertion and placement of the electrodes require "mapping" involving several trajectories, which can be significantly facilitated by a robot.

Additionally, in epilepsy surgery, *Radiofrequency Thermocoagulation* (RF-THC) and *Laser Interstitial Thermal Therapy* (LiTT) can be applied if small volumes of surrounding brain tissue need to be ablated in reoperations [3].

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Chronic high-frequency *Deep Brain Stimulation* (DBS) results in ablation of selected areas of functional brain parenchyma. This improves treatment results in motor disorders, the most common indication being Parkinson's disease. Robot-assisted insertion of stimulating electrodes into the subthalamic nucleus and the subsequent deep brain stimulation improves not only the tremor but also the rigidity and the bradykinetic symptoms and signs associated with the disorder [1, 4, 5].

Robotic assistance in taking biopsies is superior to any other method, as it enhances the surgeon's skills with accuracy and mechanical stability. It enables the surgeon to obtain multi-bite biopsies of the lesion and the surrounding tissue, enabling the correct histological diagnosis to be made through the full extent of the tumor [1].

Robotic neuro-endoscopy [6] has been applied in the resection of hypothalamic hamartomas and has also been used to relieve obstructive hydrocephalus and fenestration of cerebral cysts in pediatric patients. It has recently been used to treat hemispheric epilepsy by performing hemispherectomy [1].

There is a gradual increase in the number of indications for robot-assisted spinal surgery. A robot can guide the surgeon to deep anatomical areas through a narrow corridor while avoiding vital anatomical structures. At present, the most widely used procedures are pedicle-screw placement and anterior lumbar interbody fusion (ALIF).

During earlier robotic applications, the position of the microscope or the endoscope was the focus [7, 8], but nowadays true robotic surgery with micromanipulators and joysticks receives increasing emphasis. However, only in stereotactic functional applications can robotics really be considered to have been incorporated to a limited degree into daily clinical routine [9, 10].

The lateral skull base is a particularly challenging area for the neurosurgeon. Not only are the lower cranial nerves involved in this area but also the two carotid arteries and vertebral arteries as well as the draining veins. Additionally, many different approaches are available with distinct pros and cons depending on objective criteria and the subjective opinion of the performing surgeon.

In the following, the authors present the peculiarities of standard approaches to the lateral skull base such as the pterional and frontolateral and the retromastoid and far lateral approaches.

7.2 Pterional and Frontolateral Approaches to the Lateral Anterior and Middle Cranial Fossae

Named after the pterion, which is the junction of four bones—the temporal, frontal, parietal, and the sphenoid (greater wing)—the pterional approach is one of the five most important approaches to the lateral skull base. It is especially useful for lesions in the lateral aspect of the skull base, such as subfrontal, temporal, parasellar, tentorial, and midline lesions. It is the gold standard for microsurgical management of cerebral aneurysms involving the anterior part of the circle of Willis [11, 12]. The patient is placed in supine position and the head is slightly extended and rotated to

30–60 degrees, depending on the anatomical site of the lesion, allowing the zygoma to be the highest point. Owing to gravity, the frontal lobe then falls away from the anterior cranial fossa, facilitating access to the lesion. Slight lateral flexion of the cervical spine to the contralateral side makes the Sylvian fissure lie vertically in relation to the surgeon [13].

The authors apply this approach mainly in surgery for lesions around the internal carotid artery, the cavernous sinus, and the anterior clinoid process. The approach is presented in detail in Fig. 7.1.

The frontolateral approach is distinguished from the pterional approach by its more medial extension. The Sylvian fissure is only partially exposed. It allows the skull to be accessed via the anterior cranial fossa and to some degree the middle cranial fossa. It is often used for the resection of olfactory groove meningiomas and for subfrontal, parasellar, and tentorial lesions [12].

Preparation for the frontolateral approach shares many similarities with the pterional approach. However, since it is more frontal and more medial, the head is usually less rotated and the route is subfrontal with the frontal lobe mainly elevated, in contrast to the pterional approach, which has a rather transfissural trajectory. The authors apply this approach mainly for surgery of lesions around the internal carotid artery, the cavernous sinus, and the anterior clinoid process. It is their preferred approach because it does not require drilling most of the sphenoid wing, and only minimal dissection of the Sylvian fissure is needed. Thus, they prefer the

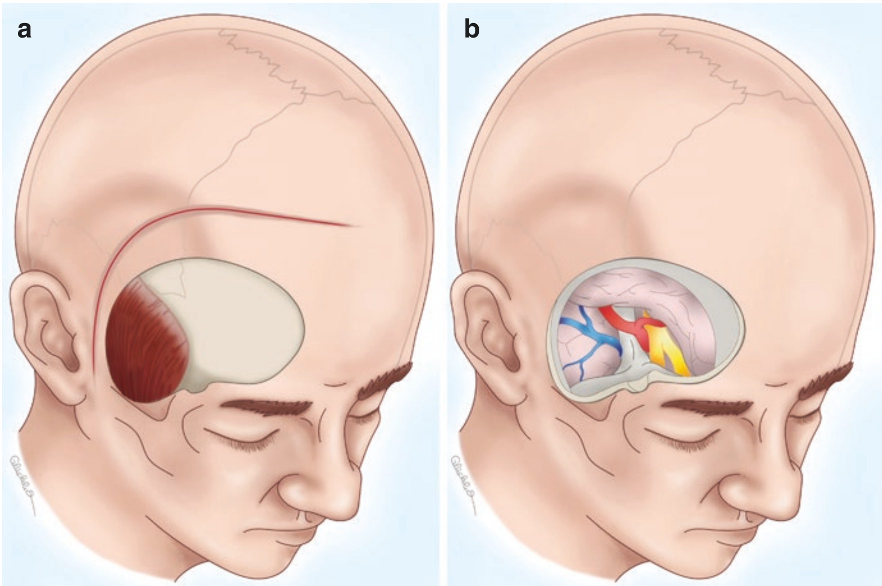

Fig. 7.1 Pterional approach (Courtesy of Laura Glucklich). (**a**) Schematic drawing of skin incision and craniotomy size in relation to pterion and temporalis muscle. (**b**) Schematic drawing of intraoperative view of carotid artery with junction of anterior and middle cerebral arteries and optic nerve. Please note the easy approach to the Sylvian fissure

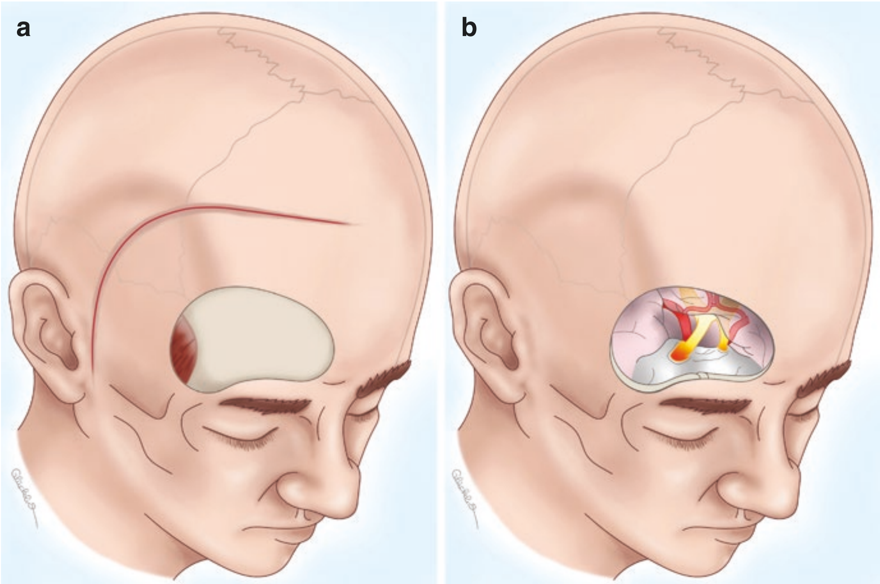

Fig. 7.2 Frontolateral approach (Courtesy of Laura Glucklich). (**a**) Schematic drawing of skin incision and craniotomy size in relation to pterion and temporalis muscle. (**b**) Schematic drawing of intraoperative view of carotid artery with junction of anterior and middle cerebral arteries and optic nerve. Please note the easy approach to the optic nerves and optic chiasm

frontolateral approach for all pathologies that do not require a trajectory from a more lateral craniotomy. The approach is presented in detail in Fig. 7.2.

To date, there has been no peer-reviewed publication detailing the application of robotics in either the pterional or the frontolateral approach. However, the authors see potential applications. A robot could easily be used in these two approaches since the skin incision and the craniotomy are rather large, so there is no obvious limitation to bringing robot-steered tools into the surgical field. In the authors' opinion, the current shortage of information is mostly attributable to the difficult anatomy within the frontolateral skull base. The close proximity of the optic, oculomotor, trochlear, olfactory, and trigeminal nerves makes this a difficult area with a high risk for complications. Furthermore, the differentiation of arteries and veins from cranial nerves and adjacent eloquent brain tissue such as the brainstem requires very sensitive tactile feedback, which is not provided by current robotic systems.

Both approaches are feasible candidates for applying robots. The craniotomy phase in both needs significant drilling and bone removal. In particular, sufficient removal of the lateral sphenoid wing with preservation of dural integrity and making the frontolateral craniotomy as medial as possible without opening the frontal sinus, appear well suited to robotic-controlled craniotomy. In the intracranial phase, very delicate structures with different tissue resistances such as arteries, veins, and cranial nerves—as discussed above—make these approaches difficult for robotics, although the expected high accuracy of a robot could lower the operative risk significantly. Therefore, the authors are convinced that robotics will become valuable for treating lesions of the anterior and middle fossa skull base via pterional and frontolateral craniotomy. However, more experience is needed before such different surgeries can be done with the aid of robotics.

7.3 Retrosigmoid (Lateral Suboccipital) and Far Lateral Approaches to the Lateral Posterior Fossa

The retrosigmoid approach is the "bread and butter" approach for the lateral posterior cranial fossa in neurosurgery. It is also one of the five most important approaches, comparable in importance to the pterional approach to the anterior and middle cranial fossa. It is especially useful for lesions in the cerebellopontine angle, at the subtentorial lateral petrous bone, and in the lateral foramen magnum. It is the gold standard for a microsurgical approach to many meningiomas, schwannomas, chordomas, and metastases in this region. The key step is to identify the asterion, the junction of the lambdoid, occipitomastoid, and parietomastoid sutures. Directly beneath these sutures run the transverse and sigmoid sinuses, which frequently have to be exposed; particular care is needed to avoid injuries to these structures.

For the approach, the patient is placed in a prone, lateral, or semi-sitting position. The authors prefer the semi-sitting position for various reasons; however, the individual preferences of surgeons vary widely. In the semi-sitting position (please also refer to reference 13) the head is slightly elevated, inclined toward the sternum and rotated 30–45° toward the lesion. Intraoperative transesophageal echocardiography is very helpful for early detection of air embolism. To reduce the risk of air embolism further, the patient's legs should be elevated, and the blood should be pooled around the chest. Therefore, the table is usually flexed to facilitate venous return.

After shaving, skin disinfection and sterile draping, the mastoid tip is located. In difficult anatomical situations, neuronavigation can be used. The site of the skin incision depends on the lesion. The greater the need to see inside the internal acoustic meatus, the more medial the skin incision should be. As a rule of thumb, the skin incision is made 3 cm behind the ear, extending from the upper ear level down to the mastoid tip. Dissection of the muscles follows, with care to avoid injury to the lesser and greater occipital nerves and occipital artery, although this is frequently not possible. Then the skull sutures and the anatomical orientation points are identified: Asterion, lambdoid suture, parietomastoid suture, occipitomastoid suture. The transverse and sigmoid sinuses are then located. Then the craniotomy is performed close to the sinus with an osteoplastic followed by an osteoclastic technique, finally exposing these veins. The osteoclastic technique includes partial mastoidectomy for exposure to the sigmoid sinus.

The authors apply this approach mainly in surgery for lesions around the cerebellopontine angle and the subtentorial lateral petrous part of the temporal bone, and lesions anterolateral to the foramen magnum. It is also the preferred approach for many vascular lesions of the posterior fossa. It is presented in detail in Fig. 7.3.

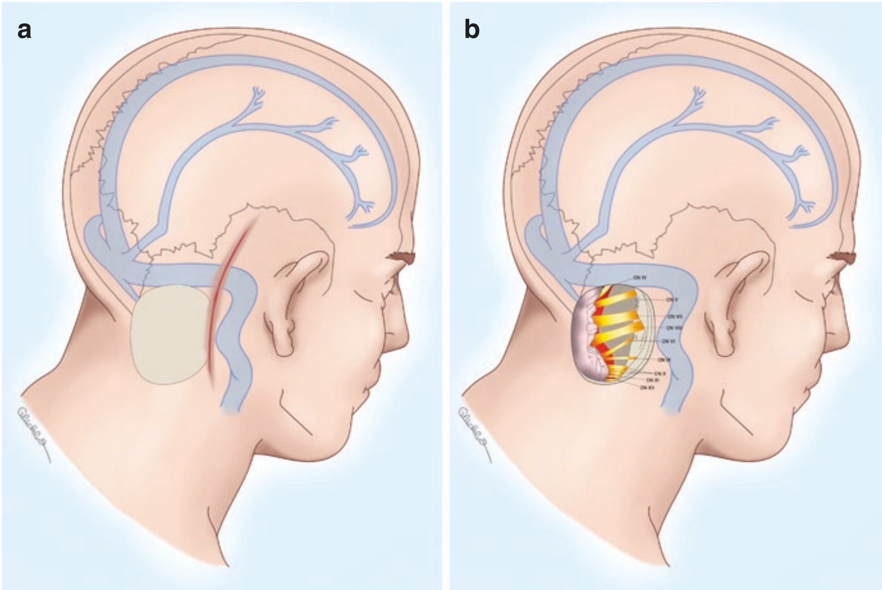

Fig. 7.3 Retrosigmoid approach (Courtesy of Laura Glucklich). (**a**) Schematic drawing of skin incision and craniotomy size in relation to the asterion and both sigmoid and transverse sinuses. (**b**) Schematic drawing of intraoperative view of the cerebellopontine angle with cranial nerves IV through XII and basilar and vertebral arteries

The far lateral approach is essentially an extension of a lateral suboccipital approach with an opening of the foramen magnum. There are many different extensions depending on which site of surgery is desired. It has therefore been dubbed the "Far lateral enough approach," as additional removal of bony components such as the condylar fossa, the occipital condyle, and the jugular tubercle is required. Following extensive removals of the condyles, dorsal stabilization should be ensured to avoid biomechanical instability of the atlantooccipital joint [13, 14].

This approach is used for access to lesions of the anterior and anterolateral clivus, the brainstem, the craniovertebral junction, and the upper spine. It is presented in detail in Fig. 7.4.

No detailed application of robotics in these infratentorial approaches has been described to date. As in the approaches to the anterior and middle cranial fossa, a robot could easily be used in these two approaches since the skin incision and the craniotomy are rather large, so there is no obvious limitation to bringing robot-steered tools into the surgical field. However, in the retrosigmoid approach, the delicate anatomy in the cerebellopontine angle makes it difficult to deploy a robot. Because of the close proximity of cranial nerves III through XII in conjunction with the vertebral and basilar arteries, this area has a high risk for intraoperative complications. Furthermore, differentiating arteries and veins from cranial nerves and adjacent eloquent brain tissue such as the brain stem requires very sensitive tactile feedback, which is not provided by current robotic systems. The application could

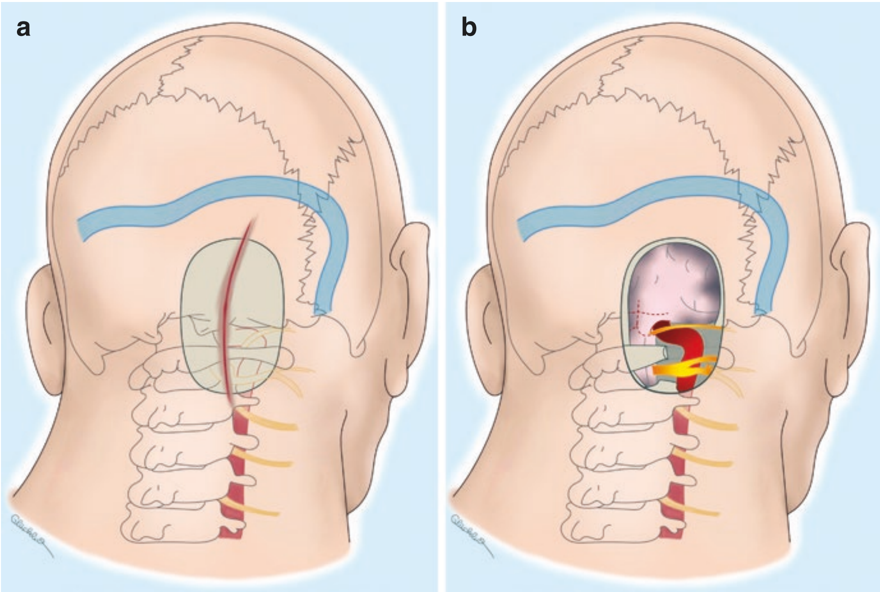

Fig. 7.4 Far lateral approach (Courtesy of Laura Glucklich). (**a**) Schematic drawing of skin incision and craniotomy size in relation to the foramen magnum, C1, and extracranial vertebral artery. (**b**) Schematic drawing of intraoperative view of the craniovertebral junction via a far lateral approach

be more feasible in the far lateral approach; but since this approach is quite rare, it is not necessarily the first choice procedure for starting robotic applications.

In summary, both approaches are feasible candidates for applying a robot. The craniotomy phase in both requires significant drilling and bone removal, as in pterional and frontolateral craniotomy. In particular, sufficient removal of the suboccipital bone with preservation of the sinus and dural integrity could be an interesting first application of a robot in these approaches. The authors are convinced that robotics will become valuable in these lateral posterior fossa approaches in the future. However, more experience is needed before such different surgeries can be performed with the aid of robotics.

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